PLANTERS' RECORD

VOL. XXXIX

A quarterly paper devoted to the sugar interests of Hawaii, and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

JANUARY TO DECEMBER

THE HAWAIIAN PLANTERS' RECORD

VOL. XXXIX

ORGAN OF THE EXPERIMENT STATION OF THE
HAWAIIAN SUGAR PLANTERS' ASSOCIATION

HONOLULU

1935

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

OFFICERS FOR 1935

R. A. COOKE	President
H. A. WALKER	1st Vice-President
F. C. ATHERTON	2nd Vice-President
R. D. MEAD	Additional Vice-President
B. H. WELLS	Secretary and Treasurer
S. O. HALLS	Asst. Secretary and Asst Treasurer
W. PFLUEGER	Asst. Secretary
JOHN WATERHOUSE	Auditor

TRUSTEES FOR 1935

EXPERIMENT STATION COMMITTEE

L. D. LARSEN, Chairman

C. R. HEMENWAY
J. E. RUSSELL
G. P. WILCOX
F. C. ATHERTON
A A SCOTT
G. E. SCHAEFER

A. R. GRAMMER, Secretary

EXPERIMENT STATION STAFF

H. P AGEE . . . Director

R. C. L. PERKINS, OTTO H. SWEZEY . . . Consulting Entomologists

C. E. PEMBERTON . . . Executive Entomologist
Associate Entomologists: F. X WILLIAMS, R. H. VAN ZWALUWENBURG.
Asst. Entomologist: FRED A. BIANCHI.

H. L LYON . . . Botany, Forestry and Pathology, in charge
J. P. MARTIN . . . Pathologist
Associate Pathologist: C. W. CARPENTER. Histologist: D M. WELLER Forest Supervisors. L. W. BRYAN (Hawaii), GEORGE A. McELDOWNEY (Oahu), ALBERT DUVEL (Kauai). Asst. Botanist: E. L CAUM. Research Assistant: HUGH W. BRODIE. Asst. in Forestry: COLIN POTTER.

W. R. McALLEP . . . Consulting Sugar Technologist

W. L. McCLEERY . . . Sugar Technologist
Assistant Sugar Technologist: RAYMOND ELLIOTT. Associate Chemists: H. A. COOK, FRED HANSSON. Assistant Chemists: WARD S. FLESHMAN, A. FABIUS.

F. E. HANCE . . . Chemist
Associate Chemists: L. E. DAVIS, F. R. VAN BROCKLIN. Assistant Chemists: ARTHUR AYRES, A. R LAMB, PAUL GOW.

J. A. VERRET . . . Consulting Agriculturist

A. J. MANGELSDORF . . . Geneticist
Associate Geneticist: COLIN G. LENNOX. In charge Kailua Variety Station: H. K. STENDER.

R. J. BORDEN . . . Agriculturist
Associate Agriculturist: R. E. DOTY. Plant Physiologist: DOUGLAS A. COOKE.

Island Representatives (Genetics and Agriculture): F. C. DENISON (Oahu), O. H. LYMAN (Hawaii), D. S. JUDD (Maui), C. C. BARNUM (Kauai).

A. H. CORNELISON	Supervisor Fertilizer Control
U. K. DAS	Research Asst., Director's Office
W. TWIGG-SMITH	Illustrator
A. R. GRAMMER	Chief Clerk
MABEL FRASER	Librarian

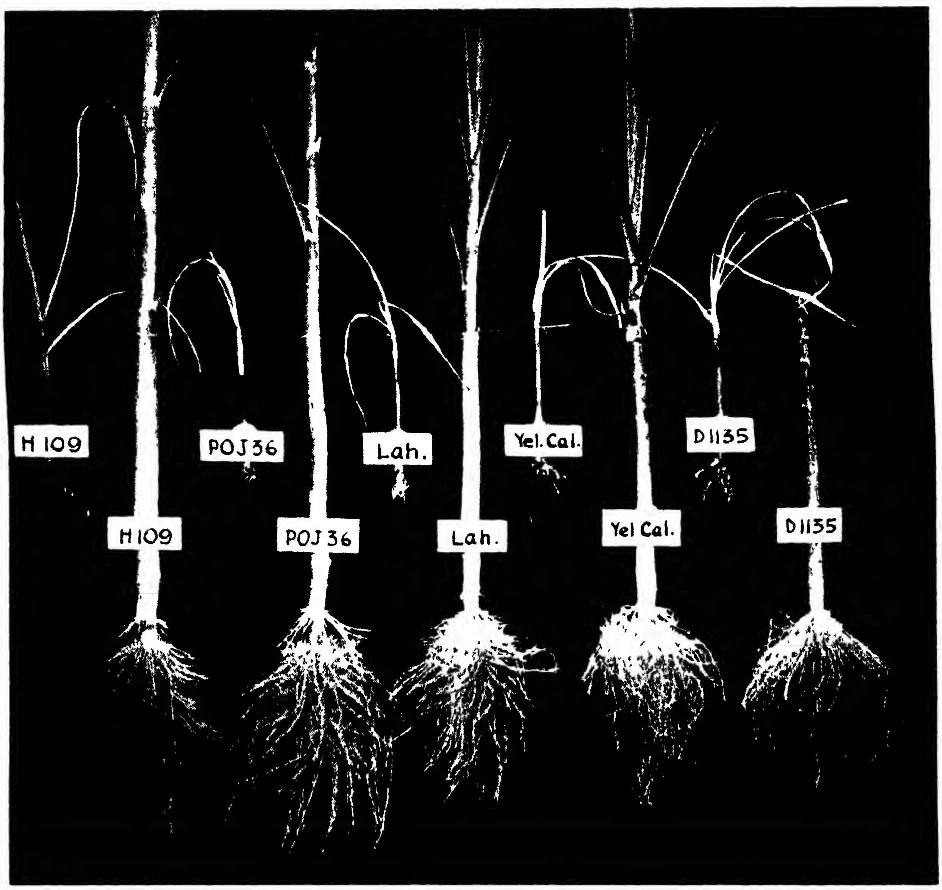
TABLE OF CONTENTS

ILLUSTRATIONS APPEARING ON THE COVERS OF VOLUME XXXIX

FIRST QUARTER

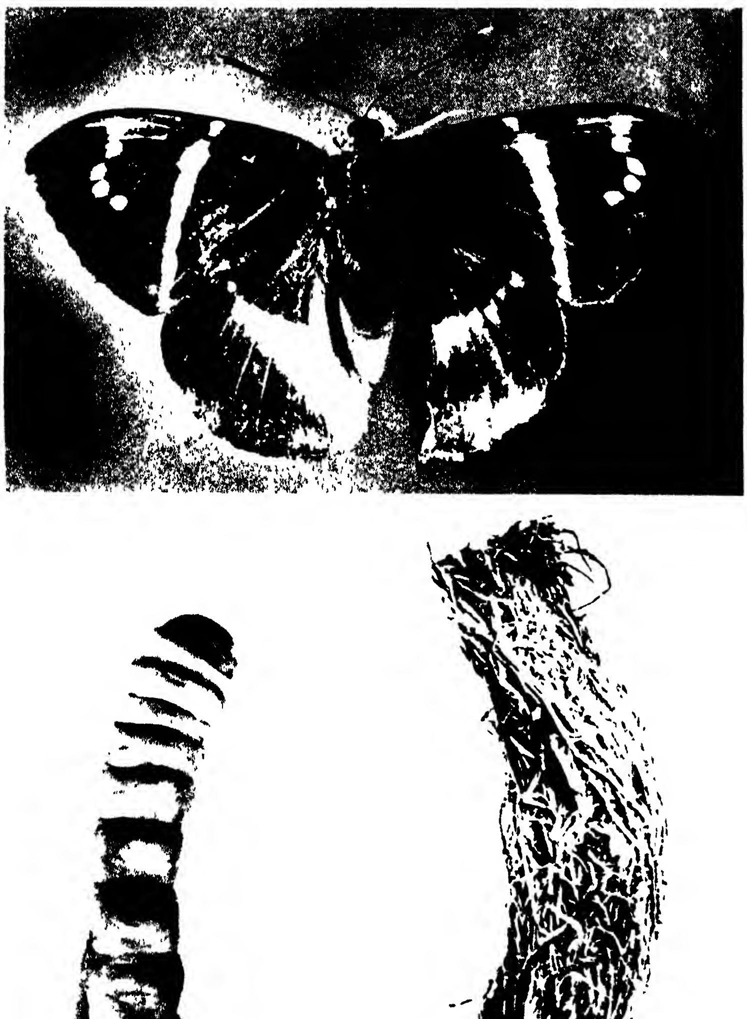
Sugar cane is being crossed here under a system of mass pollination whereby several hundred cane varieties are brought together for the purpose

SECOND QUARTER



The large sugar cane plants were grown in a complete nutrient solution which was prepared with tap water and acidified or adjusted to a pH value of 5.0 to 5.2 by adding sulphuric acid. The small plants were grown in a similar nutrient solution which was not acidified. The pH value of the latter was 5.8 to 6.0 (see text).

THIRD QUARTER



The giant sugar cane moth borer of Tropical America. The most serious of all insect pests of sugar cane. This moth hatched from a shipment of ornamental plants recently imported to Honolulu from the Canal Zone, Central America. Fortunately the plants were in quarantine, thus preventing the escape of the moth.

FOURTH QUARTER

Sugar cane of the variety H 109, thirteen months of age, which is being used in a cooperative study of the effect of water upon the formation and transport of sugar and the ripening of cane.

THE HAWAIIAN
PLANTERS' RECORD

Vol. XXXIX FIRST QUARTER, 1935 No. 1

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

Another Step in Cane Breeding

A development in sugar cane breeding is that of using cane tassels in mass formation The arrangement is shown on the cover of this issue The object is to increase the chances of obtaining combinations that may hold rich possibilities of producing outstanding canes Under this type of mass pollination we suffer a loss in the pedigree of the new canes, because the male parent remains unidentified among the hundreds of cane varieties brought together in this sugar cane melting pot

However, we must sacrifice either the pedigree or the offspring itself because it is beyond the realm of practicability to cross, under isolation from contaminating pollen, as many matings as are thus given an opportunity to be realized

To illustrate, if the hundreds of cane varieties shown under mass pollination in the picture were each mated separately with each of the rest we should need to arrange for over 100,000 such matings.

In the past we have found it practicable each year to bring about approximately 500 separate crossings, or trial marriages, as they call them at the Java station. Such crosses between selected parents are of course to be continued.

But we might, by use of the older system alone, defer for years—or scores of years—sugar cane combinations of exceptional interest and commercial value that may already have come about in our first mass pollinations.

The Genetics Department is putting this new development into practice following conferences on the part of A. J. Mangelsdorf during the past summer with geneticists on the mainland, where the idea is being employed for other crops.

Mass pollination of this type with sugar cane is dependent upon the sulphurous-phosphoric acid method of preserving cane tassels in a fresh and functioning form. It is a scheme originated at this Experiment Station through the researches of Verret, Das, and others.

It is of interest to speculate upon the millions upon millions of possible combinations when we contemplate crossing hundreds of cane varieties, each male with 40 or more chromosomes, each female with 40 or more chromosomes.

On just a few square feet of ground in a coconut grove at Kailua, Oahu, there have been brought together the sugar cane blood lines from India, China, Australia, Java, New Guinea, and islands of the South Seas—in a genetical orgy such as the genus *Saccharum* has never known before.

In This Issue:

Irrigation:

An interesting development in irrigation is described as the flume system or long-line herring-bone. This contribution to sugar cane culture on the part of Mr. H. W. Baldwin promises to be one of definite importance. The plan as described, or some of the modifications of it that are sure to follow, are likely to find a place in Hawaiian irrigation, for the scheme in principal has the advantage of doing away with many level ditches with their costly seepage losses, and presents a semi-automatic way of distributing water at a great reduction in labor.

The Hand Refractometer:

The hand refractometer and juice punch are described as a kit suitable for obtaining a rapid and relatively accurate measure of sucrose content in growing cane.

Fundamental studies on the sampling error in a field of cane are presented to show the degree of accuracy which may be expected from this kit.

The practical applications of the kit to plantation operations are pointed out. It is of value as a means of measuring ripening of fields soon to be harvested, profitable height of topping in the harvesting field, and finally as a means of studying the rate of sugar storage in new varieties.

A description is given of the use of this kit in Formosa.

Cane Growth:

Comparisons in the cane yields are often complicated on account of the two variables, one that of soil, the other that of climate. With the intent of noting the effect of climatic differences alone, a little study was undertaken using large concrete tubs filled with the same soil. Some of the tubs were placed at Makiki, others in the upper reaches of Manoa valley. Two varieties of cane were used in both places, P.O.J. 2878 and P.O.J. 36.

We all know, of course, that the climate of the lowlands is superior for cane growth to that under cloud banks in the uplands. Here, however, we have a quantitative measure of this difference, undisturbed by the factor of soil variation. The study is another small step in building up our basic information on the sugar cane plant, and its environmental influences.

Fertilizer:

Upon occasion the fertilizer programs of different plantations have been published. This subject is now brought up to date. The same plan as used before of depicting a fertilizer program has been followed. It puts before one in clear compact form: the kind of fertilizers; the amount of fertilizer; the composition of fertilizers into percentages of nitrogen, phosphate, and potash; and the pounds per acre of each of these ingredients applied at each application. The time of each application is also shown. Anyone not familiar with the scheme of presentation needs only to refer to the key on page 33.

Flume System of Irrigation*

(LONG-LINE "HERRING-BONE")

By H. W. Baldwin

Last year at this time we presented a preliminary report of a new adaptation of the long-line herring-bone or "Flume System" of irrigation being carried on by Maui Agricultural Company, Ltd. The system has given such gratifying results during the intervening months that we are presenting herein the complete performance record to date.

The flume system in this experiment consists of 29.7 acres with lines averaging 217 feet in length with a grade of 3 per cent. This is a very porous soil and has always been a heavy consumer of water. The 3 per cent grade from all appearances is about right for this type of soil. All portions of the lines seem to have had sufficient water, and that, without the need of opala in the lines. The cane appears to be every bit as good as that in the check plot which consumed 54 per cent more water.

All water used was measured by the engineering department by means of concrete Parshall flumes with Stevens water stage registers.

The size of flumes used in this experiment was 6″x 12″, i.e., 1″x 12″ floor with 1″x 6″ sides. In our paper last year we endeavored to show by means of cost curves, etc., that a flume of twice the capacity even at double the cost would be more economical. This point is again brought out in the table of "Cost of Flume System per Acre" found herein. For example: Assuming that the system will be used for at least four crops and that there will be 40 irrigation rounds per crop, or a total of 160 rounds, and that the contract irrigators will be on approximately a \$2.50 per day basis (\$2.00 for wages and \$.50 for overhead) instead of \$1.00 per day as shown in the table, the total cost of the 160 rounds with the three sizes of flume listed will compare as follows:

		\$1.00 Basis	\$2.50 Basis
6″x 6″ Flume	160 Rounds	\$40.00 per Acre	\$100.00 per Acre
6″x 12″ "	160 "	20.00 " "	50.00 " "
10″x 12″ "	160 "	10.00 " "	25.00 " "

It is obvious that the largest size flume is the most economical, as the saving in labor cost more than offsets the extra cost of the flume.

In accordance with these findings we have this year planted 115 acres to the flume system, using 10″x 12″ redwood flumes, instead of 6″x 12″, thereby adding four inches to the sides, which doubled the capacity and increased the cost by only one-third.

* Presented at the Thirteenth Annual Meeting of the Association of Hawaiian Sugar Technologists, Honolulu, 1934.

There have been thirteen rounds of water applied to date and the best performance so far is 17 acres per man per day. The last few rounds gave the following results:

Round	Acres per Man	Acre Inches per Acre	
9	17.08	2.98	
10	13.52	3.88	(Shortage of water accounts for less acres per man)
11	12.10	4.55	"
12	16.5	3.51	
13	15.7	3.70	(Estimated)

So far we have confined our use of the flume system to the steeper parts of the fields having a slope of 5 per cent and over, where other long-line systems are either unsatisfactory or impossible. But with the increased use of this system we are beginning to realize that it can be so planned as to reduce the use of straight ditches and costly water gates and numerous level ditches with the attendant seepage losses. We have become accustomed to ignore level-ditch seepage losses believing them to be unpreventable. It is frequently stated that this seepage water is not lost but benefits the cane, citing in support of this contention the fact that the cane bordering level ditches has a better growth than that farther away from the ditch. But isn't it just possible that this growth is due to the larger feeding area available for the roots, and to the absence of vegetation in the ditches to absorb the moisture? At any rate, to our knowledge, not much, if any, study has been given to level-ditch seepage losses; but now that it is dawning upon us that these losses can be eliminated by the use of flumes it becomes important to find out if the losses are great enough to justify the use of flumes on the flatter lands.

To this end we solicited the aid of J. H. Hofmann, of the engineering staff, and he has made a careful study of level-ditch seepage losses on various fields of both young and old plant cane and upon ratoon fields of various ages. Small, portable, galvanized Parshall flumes were installed in the ditches, one at the head and one at the end of the ditch. Water was allowed to flow through the ditch with all outlets closed for a period of over four hours, ten-minute readings were taken of the gauge heights, and the total water flowing through the respective flumes was then calculated. The difference between the two totals gave the loss, and this divided by the length of ditch gave the loss in cubic feet per foot of ditch per minute. Following are the results secured on this very porous soil:

RESULTS OF LEVEL-DITCH SEEPAGE MEASUREMENTS

Date	Field	Age of Ditch		Length Feet	Time Hrs.	Min.	Loss in Cubic Feet per Foot per Minute
9/ 4/34	4	4	months	859	4	9	.033
9/ 7/34	61	15	"	594	4	9	.042
9/ 7/34	6	2	years	504	4	30	.028
9/11/34	7	2 1/4	"	355	4	5	.055
9/13/34	5	4	"	420	4	7	.033
9/12/34	7	7	"	661	4	55	.051

Having determined the seepage loss in cubic feet per foot of ditch per minute, Mr. Hofmann next proceeded to determine what the loss in acre inches amounted

to during one irrigation round on an area of 95.36 acres, in Field 4. By means of stop watches the number of minutes that water flowed in each foot of level ditch during the complete round was recorded. Then using the factor of .033 cubic feet per foot per minute pertaining to Field 4, the loss was determined to be 41.00 acre inches. This would be sufficient to irrigate 13.65 acres to a depth of 3 inches.

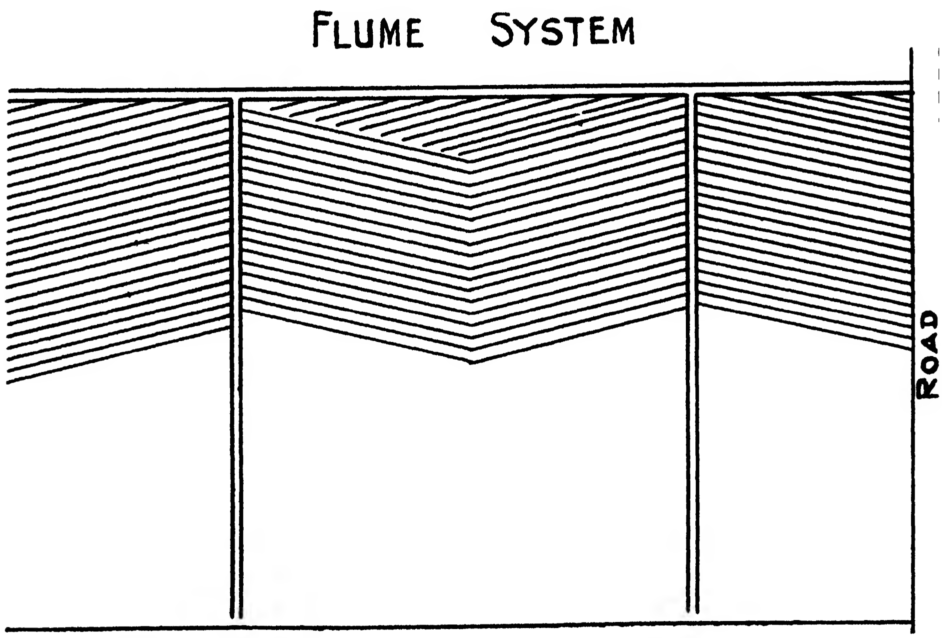


Fig. 1. Showing flume system on a 10-acre field with 15 per cent slope. The layout would be the same on any slope and is entirely satisfactory on maximum slopes. Note uniform length of lines, also absence of level ditches.

Costs:

680-foot flume (10"x 12")	$170.00
16 watercourse boxes for short lines at head	5.75
2 single water gates	7.00
Cost per 10 acres	$182.75
Cost per acre	$ 18.27

Performance:

Best performance to date, 17 acres per man per day. Last rounds (12th and 14th) 16.9 acres per man per day.

This diagram represents ideal conditions which of course seldom exist in the field and the low cost for the flume system as shown in Fig. 1, could not quite be attained except under such ideal conditions. However, these cost figures serve to bring out the point that the cost of the flume system is not as prohibitive as is generally supposed. Considering the fact that straight ditch gates and level ditches are largely eliminated by the use of flumes, it is seen that there is not much difference in cost between this system and other long-line systems in extensive use.

In light of the foregoing facts it would seem that the matter of using the flume system on loose, porous soils for the purpose of eliminating level-ditch seepage

losses deserves deep consideration. In conclusion, we feel that the flume system has now proven itself to be highly efficient as to economy in both labor and water.

FLUME SYSTEM VS. CONTOUR SYSTEM
FIELD 61 PERFORMANCE RECORD

FLUME SYSTEM 29.7 Acres (6" x 12" flume)					CONTOUR SYSTEM 21.55 Acres			
Date	Men	Acre Inches per Acre	Acres per Man	Round No.	Acre Inches per Acre	Acres per Man	Men	Date
July 13	8	3.88	2.97	1	6.30	.47	45	July 19
" 17	14	3.76	2.15	2	3.45	1.43	15	" 24
" 24	6	5.32	4.95	3	3.75	1.35	16	Aug. 2
Aug. 1	4	4.57	7.45	4	3.41	1.12	17½	" 10
" 9	4	4.39	7.45	5	3.06	1.54	14	" 17
" 17	3¼	3.16	9.15	6	5.85	.72	29½	" 31
" 30	3¼	4.67	9.15	7	5.87	.68	31¾	Sept. 12
Sept. 11	4	5.32	7.42	8	5.63	.54	33½	" 23
" 22	3.3	5.49	9.02	9	5.60	.86	25	Oct. 5
Oct. 4	3.5	3.88	8.50	10	6.58	.74	30	" 17
" 16	3.4	6.17	8.70	11	6.57	.68	31½	" 31
" 28	4.8	3.95	6.18	12	6.36	.63	34	Nov. 17
Nov. 15	5.6	3.83	5.30	13	7.83	.88	24.3	Dec. 11
Dec. 18	6.2	5.41	4.80	14	5.00	1.27	17	" 20
Jan. 8	6	5.80	4.95	15	6.21	1.21	17.7	Jan. 5
" 18	5.4	4.66	5.50	16	5.31	1.54	14	" 20
" 31	5	2.92	5.94	17	7.13	1.92	11 2	Feb. 7
Feb. 12	4½	4.17	6.60	18	6.43	2.69	8	" 18
" 23	3¼	3.75	9.14	19	6.77	2.69	8	March 2
March 7	3¼	4.62	9.14	20	7.70	2.87	7½	" 13
" 16	3	4.35	9.90	21	10.99	2.87	7½	" 23
" 26	3	4.90	9.90	22	6.57	3.59	6	April 1
April 3	2.5	3.52	11.90	23	7.15	3.04	6½	" 17
" 19	3.5	4.88	8.50	24	9.27	2.27	9½	May 1
May 4	3.5	5.23	8.50	25	11.20	2.15	10	" 20
" 23	5.0	6.43	5.93	26	11.20	2.80	7½	June 1
June 4	4	7.32	7.40	27	10.38	2.80	7½	" 13
" 15	4¼	6.65	7.00	28	11.11	2.80	7½	" 22
" 25	4¼	7.11	7.00	29	14.60	2.53	8½	July 7
July 6	4	7.59	7.42	30	12.29	2.53	8½	" 18
" 17	5½	7.12	5.41	31	12.40	2.69	8	" 30
" 29	5	8.09	5.94	32	18.85	1.79	12	Aug. 22
Aug. 9	5	7.63	5.94	33	15.84	2.22	9.7	Sept. 10
" 28	7	11.68	4.24	34	15.60	2.26	9.5	" 30
	160.2	182.22			282.26		548.65	

Total Acre Inches Applied per Acre to Date on Contour System...... 282.26
Total Acre Inches Applied per Acre to Date in Flume System..... .... 182.22

Amount Saved by Flume System.. 100.04
The Contour System Used 54.9 Per Cent More Water Than the Flume System.

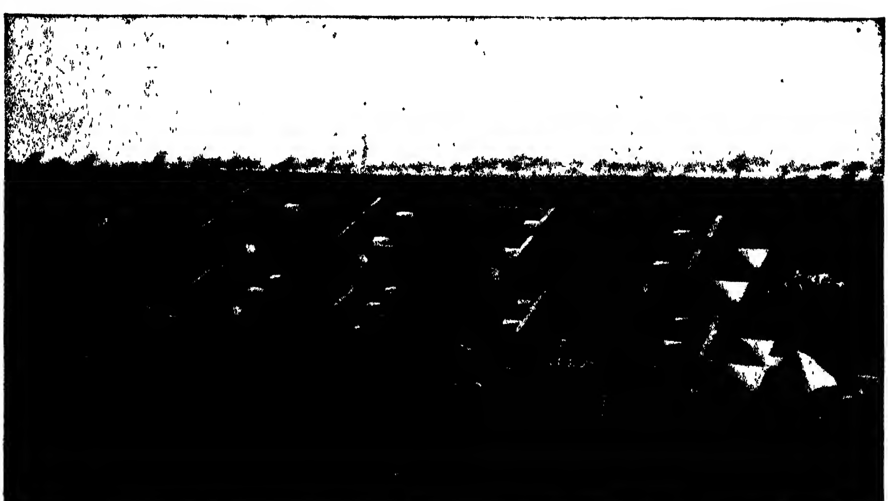
Cost of Flumes: In comparing costs of different systems it is necessary to take into account the length of lines used. Obviously, a flume will serve more acres if the lines are 300 feet in length than if they are only 200 feet. For that reason we have tabulated flume costs according to various lengths of lines and also with different sizes of flumes in both northwest and redwood lumber. To enable one to determine the most economical size to use, the expected performance must also be taken into account. We have incorporated this in the cost table in accordance with our experience with the systems thus far.

COST OF FLUME SYSTEM PER ACRE
COMPLETE WITH FLUME GATES

Length of Lines	Lines per Acre	Lineal Feet Flume Per Acre	Size of Flumes		Cost per Acre: Dollars	Performance: Acres per Man Day	Labor Cost per Acre per Irrig. at $1 Day
			Side	Floor			
200 feet	48	108-132	6″	6″	NW 15-18 RW 17-21	4	$ .25
			6″	12″	NW 17-21 RW 20-25	8	.125
			10″	12″	NW 22-27 RW 26-32	15	.066
268 feet	36	81-99	6″	6″	NW 11-13 RW 13-16	4	.25
			6″	12″	NW 13-16 RW 15-18	8	.125
			10″	12″	NW 16-20 RW 20-24	15	.066
300 feet	32	72-88	6″	6″	NW 9-12 RW 11-14	4	.25
			6″	12″	NW 11-14 RW 13-16	8	.125
			10″	12″	NW 14-18 RW 17-22	15	.066

(Note: It will be observed that the performance per man day is shown as the same regardless of length of lines. We have assumed that the longer lines would be used only on tight soils and that the increased velocity of the water over that obtained in loose soils would compensate for the extra length of lines. This may be a wrong assumption, but, on the other hand, the performance may even be greater on the longer lines. We have no figures bearing on this point. However, a flume will carry 5 cubic feet more or less per second, depending on the grade. This will amount to about 50 acre-inches per ten hours. If the soil is such that as little as 2 inches per acre can be applied, 25 acres would be irrigated in ten hours, or with a 3-inch application 16.6 acres would be irrigated in ten hours, etc.)

Flattening bottom of single furrow for flume installation.

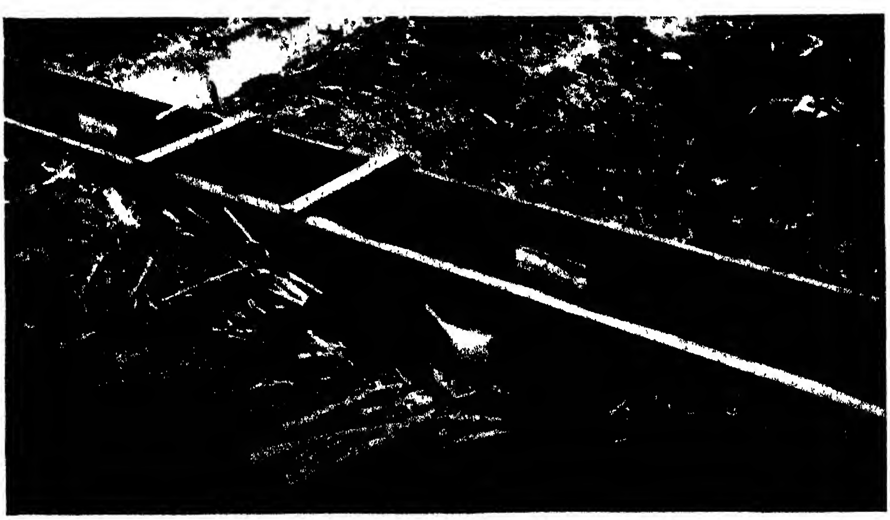


Flumes ready for installation.

Cane trash being installed under each gate in flume.

Placing flume.

Pulling up head lines to flume.



Flume gate ready for irrigation.

The flume in use.

Flume irrigation; note the herring-bone arrangement of furrows.

Applications of the Hand Refractometer in Sugar Cane Research

I. Fundamental Studies in Sampling Sugar Cane for Sucrose—C. G. Lennox.
   A. The stalk-to-stalk error in a population of sugar cane stalks.
   B. Correlation between Brix and per cent recoverable sucrose.
   C. Correlation between Brix of the lower, middle, and upper portions of the stalk with per cent recoverable sucrose from the whole stalk.

II. Basic Studies with the Hand Refractometer—U. K. Das.

III. Some Practical Uses for the "Punch Juice Sampler" and Hand Refractometer in the Cane Fields—C. G. Lennox.
   A. Comparative studies on seedlings.
   B. Preharvest juice sampling to determine relative ripeness of fields.
   C. An aid in determining the profitable height for topping the cane in the harvesting field.

IV. Use of "Punch Juice Sampler" and Hand Refractometer in Formosa —Y. Kutsunai.

I. Fundamental Studies in Sampling Sugar Cane for Sucrose

A. The Stalk-to-Stalk Error in a Population of Sugar Cane Stalks.

A crop of sugar cane growing on an area of ground is composed of a population of individual stalks which are all related in conformation and sucrose content but by no means identical. A stalk-to-stalk analysis will show differences in diameter, length, specific gravity, fibre, sucrose content, and many other qualities. These are all sufficiently different so one could not choose any one or few stalks and say that they are absolutely representative of the population. The only absolute measure is to take the entire population, but this being impossible, the next best thing is to take enough stalks to feel certain that the sample will be an approach to the true figure within a known range of error.

The purpose of this section of the paper is to examine the stalk-to-stalk variation in sucrose content of different populations of sugar cane and find a means of arriving at the closest estimate of the true figure for the entire population. To do this the standard procedure for obtaining the "probable error of a single observation" is used in connection with a formula used by F. E. Denny (3, p. 49) which calculates the number of individual observations needed to obtain a mean which will be within a desired range of error. The formula is as follows:

$$N = \left(\frac{3.2 \times \text{P.E.s.o.}}{\text{Expected Deviation}} \right)^2$$

N is the number of individuals needed to obtain a sample which will be representative of the entire population for a specified "expected deviation."

P.E.s.o. is the probable error calculated for each individual in the population and is obtained by making a number of individual stalk analyses.

Expected Deviation is the amount of error the investigator is willing to attach to his findings, i.e., a three per cent or six per cent or any other error which the case in point may seem to justify.

3.2 is the coefficient in the table of odds which is equivalent to odds of 30 : 1.

The following data will illustrate the use of the formula and also the stalk-to-stalk variation in sucrose content. The data are from mature stalks of cane 17 months old at harvest and grown on the Makiki plots. In each variety 10 mature stalks were chosen and each stalk crushed separately in a small mill which extracts from 50 to 60 per cent of the available juice. The juice from each stalk was analyzed in the routine manner for the total per cent recoverable sucrose.

Variety	Average per cent recoverable sucrose for 10 stalks	P.E.s.o. in per cent	By Denny's formula the *number* of *stalks* required to give the true per cent recoverable sucrose within the limits of an error of: 3 per cent	6 per cent
28-1234	15.0	2.7	8	2
27 C 556......	11.8	4.0	18	5
26 C 189......	13.0	5.5	35	9
H 109	13.2	7.3	61	15
25 C 28........	11.4	10.3	120	30
28-916	8.0	16.3	300	76

These figures illustrate the necessity of finding the individual variation in a population before an attempt is made to select the number of individuals needed to give an adequate measure of the true mean for the whole.

The practical difficulties involved in using the whole length of stalk are evident when it is realized that in a field where the probable error of a single stalk was found to be 7.3 per cent it would necessitate cutting out 61 whole stalks to obtain a sucrose figure on which the odds were 30 : 1 that it will be within 3 per cent of the true mean for all the stalks in the neighborhood of the sampling station. Then if the conditions within the field are sufficiently variable as to require a number of sampling stations, say one for each 10 acres, we would find it necessary to remove 610 stalks from a 100-acre field every time a preharvest sample is taken. It is difficulties of this sort that have led sugar investigators to consider other means of finding the sucrose content of a field.

Reports from Java and Formosa tell of the use of a punch which extracts a few drops of juice from a stalk for a reading of total solids in solution (Brix) by the hand refractometer. This system allows for the sampling of many stalks with little or no injury to the crop of cane. Its reliability is based upon the assumption that Brix is a good measure of sucrose content.

B. Correlation Between Brix and Per Cent Recoverable Sucrose.

The first record of an effort to measure the correlation between Brix and per cent recoverable sugar at the Experiment Station was in 1917 when a correlation chart was constructed from the Brix and recoverable sucrose analyses of a population of seedlings. Since that time the coefficient or correlation factor for Brix

versus recoverable sucrose has been calculated for a number of other populations. These are summarized as follows:

Description of population	Coefficient of correlation factor	Probable error of coefficient of correlation factor
472 seedlings in Alexander plot of 1918 propagation........	.925	±.004
576 seedlings in Makiki plot of 1917 propagation.......... ..	.974	±.001
928 seedlings in Makiki plot of 1917 propagation..	.954	±.002
1,028 seedlings in Makiki plot of 1927 propagation..........	.935	±.003
504 stools of H 109 variety in Field 21, Waipio..............	.875	±.006

The high degree of correlation which exists between Brix and recoverable sucrose, as shown by the calculated coefficient, would indicate that Brix can be used with assurance as a measure of sucrose content where a high degree of accuracy is not needed or possible to obtain. In other words a more accurate figure for the sucrose content of a field can be obtained by increasing the number

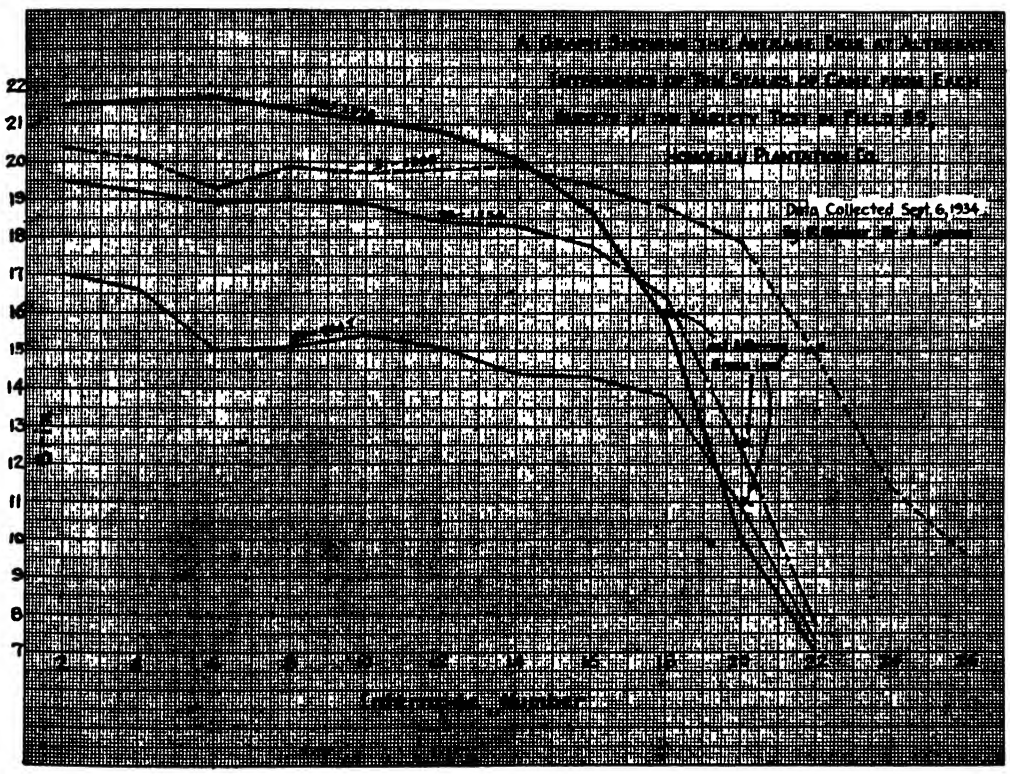


Fig. 1. The Brix remains relatively constant in the mature dry-leaf portion of the stalk 6 to 8 internodes below the last adhering green leaf, and becomes progressively lower as the immature green-leaf portion is approached and entered.

of stalks sampled and thereby decreasing the larger sampling error, and using Brix as a measure of the recoverable sucrose in this juice, rather than taking a fewer number of stalks on which a complete analysis for sucrose content can be made for the sake of reducing the relatively small error of Brix as a true measure of sucrose.

C. Correlation Between Brix of the Lower, Middle, and Upper Portions of the Stalk with Per Cent Recoverable Sucrose from the Whole Stalk.

At what point in a stalk of cane will a sample of juice be most representative of the whole stalk? U. K. Das (2, pp. 63-68) has shown that there is little change in the Brix of the internodes in the dry-leaf portion of the stalk. Similar studies conducted on seedlings (Fig. 1) show that there is little change in Brix in the internodes between the sixth or eighth internode below the last adhering green leaf. It would therefore be reasonable to assume that the juice from the middle portion of the stalk would be most representative of the whole.

In 1927 a study was conducted with 1,028 seedlings growing in the Makiki plots in which a composite juice sample was drawn from the lower internodes of each stalk in a seedling stool, one from the internodes in the middle section of stalks, and one from the upper internodes in the region of the green leaves. The samples were taken by cutting a small section from the stalk and squeezing out a few drops of juice from each section with pliers. A Brix reading was made with

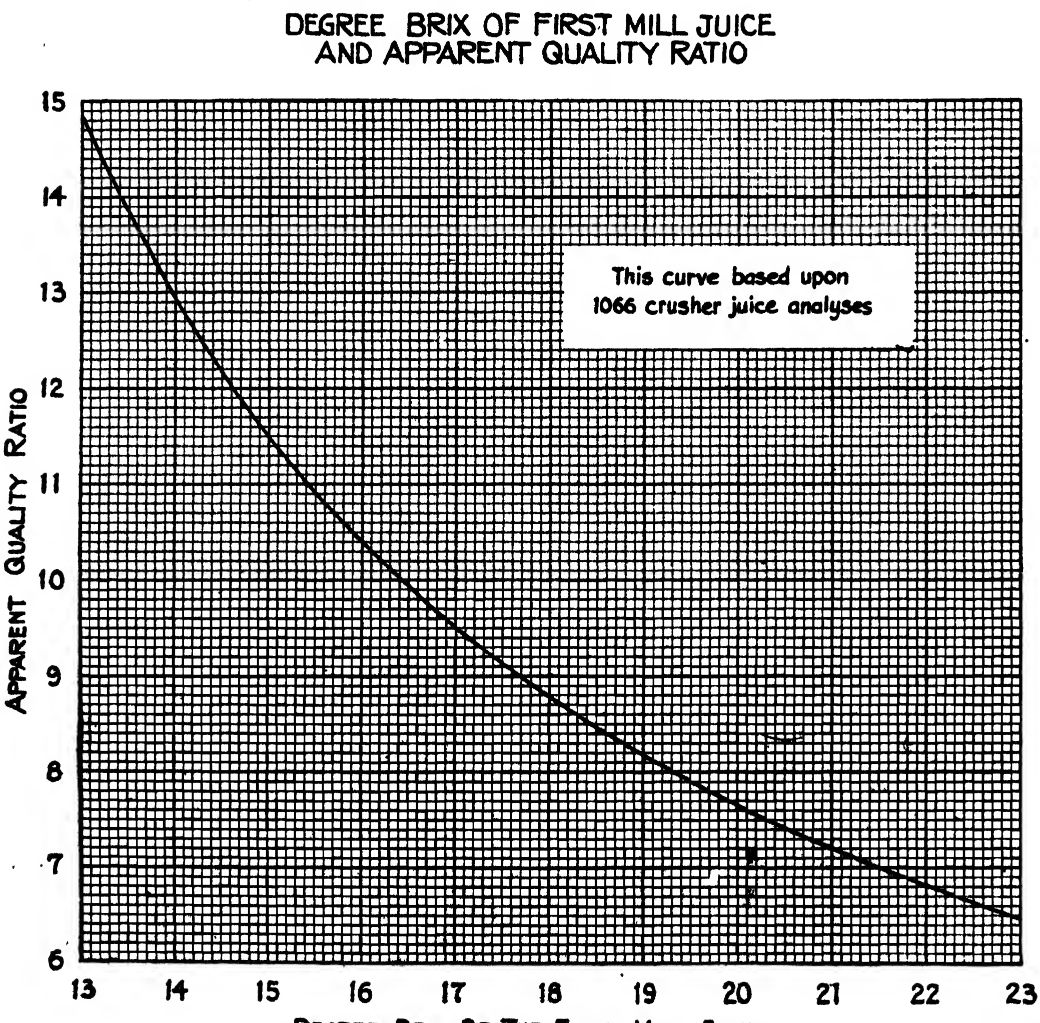


Fig. 2. Brix is a good measure of Quality Ratio where normal Purities exist. Interpolation on the curve above will give a good measure of Quality Ratio in such cases.

a hand refractometer on each of these composites. The entire stool of cane was then crushed in the small mill and the juice given the routine analysis for per cent recoverable sucrose. Correlation coefficients were then calculated for the Brix at the different locations in the stalk versus the final per cent recoverable sucrose. These are as follows:

Description of correlation	Coefficient of correlation factor	Probable error of coefficient of correlation factor
Brix of lower internodes vs. per cent recoverable sucrose from entire stool	.694	$\pm$.012
Brix of middle internodes vs. per cent recoverable sucrose from entire stool	.707	$\pm$.012
Brix of upper internode vs. per cent recoverable sucrose from entire stool	.495	$\pm$.012

These coefficients of correlation factors clearly show that the mature portion of the stalk is the best source of a juice sample which will be most representative of the whole.

The next item to be checked before the "juice punch" and hand refractometer can be used with surety in the field is the number of stalks which must be sampled to give a figure which is reasonably close to the true mean. The probable error of a single stalk can be quickly determined by reading the Brix on 15 to 25 individual stalks in the field and calculating it by Bessel's formula:

$$\text{P. E. (single observation)} = .6745 \sqrt{\frac{\Sigma\, d^2}{n-1}}$$

Then with the use of Denny's formula, explained in the early part of this paper, it is possible to find the number of stalks needed for the different degrees of accuracy desired. For purposes of illustration the following data are presented on four varieties growing in an experiment at Honolulu Plantation Company. The cane is in Field 89 and was 12 months old at the time the stalks were sampled with the punch sampler and the juice read for Brix by the hand refractometer.

Variety	Average Brix for 25 stalks	P.E.s.o. in per cent	The *number* of *stalks* required to give the *true Brix* within the limits of an error of: 3 per cent	6 per cent
31-1389	18.4	4.4	22	6
P.O.J. 2878	21.7	1.9	4	1
28-1234	17.4	3.8	16	4
29-7617	16.6	4.8	26	7

These figures show a greater degree of variation in stalk-to-stalk analyses in some varieties than others. It is likewise true that some fields of the same variety will show a greater degree of variation than others.

Summary: In sampling a population of sugar cane stalks for the best measure of the sucrose content, the greatest error to overcome is the stalk-to-stalk variation. The number of stalks needed for a reliable figure for such a population increases rapidly as the stalk-to-stalk variation increases, with the result that in many cases

the number required is beyond practical field scale operation. A punch sampler has been developed which draws a few drops of juice from a stalk without injuring it and is so rapid in manipulation that many stalks can be sampled with little effort. A coefficient of correlation factor is shown which indicates that a sample of juice drawn from the middle dry-leaf portion of the stalk is the best representative sample of the whole stalk. A hand refractometer reading of the juice sample will tell the total solids in solution (Brix) which is a reliable measure of per cent recoverable sucrose. This premise is supported by numerous correlations between Brix and recoverable sucrose. A method is described by which the number of stalks needed to obtain a true measure of the Brix for the population can be calculated for different expected errors.

II. Basic Studies with the Hand Refractometer

The usual method of cutting cane stalks in the field and bringing them to the laboratory for the extraction and subsequent analysis of juice is admittedly a burdensome process.

This method is also not very satisfactory when an attempt is being made to study the joint-to-joint variation in juice quality in order to gain an understanding of the fundamental manner in which sugars accumulate in cane. Furthermore, this method is of no use whatsoever when it is desired to study the changes in the same part of the plant from time to time.

The development in recent years of a suitable instrument for puncturing the joint and extracting the juice has opened up a large field of fruitful research. Equipped with this instrument and the hand refractometer we are now in a position to study the joint-to-joint variations in a large number of cane stalks in a very convenient manner within a short time. Moreover, we can with proper precautions, study the changes that take place in the same joint as the stalk grows older.

A large amount of work of this nature has been done at the Experiment Station in the last two years and some of the results have already appeared in *The Hawaiian Planters' Record,* First Quarter, 1934. From these extensive studies, we have found that a cane stalk can be divided into two main portions from the point of view of sugar concentration—namely, the dry-leaf part and the remaining portion of the stick containing the millable green-leaf cane and the non-millable top. The dry-leaf part is that part of the stalk where the leaves that were once firmly attached to the nodes have died and fallen off. In general we find that the concentration of Brix is quite uniform from joint to joint within the entire dry-leaf section, but that it falls off rapidly and steadily from that point on as we go farther up the stalk. In interpreting the data we have come to the tentative conclusion that accumulation of sugars in a cane stalk is a joint-by-joint process and that by the time the leaf attached to a joint has fallen off, that joint has already attained a state of maturity. In other words, these joint-to-joint studies indicate that accumulation of sugar in cane is not to be looked upon as something distinct or apart from the general growth process. As the cane grows a joint is formed, and that joint matures. Even in an 8 or 10-month-old stalk there are joints that have already reached as high or almost as high a concentration of sugar as they ever will.

In the final analysis the most fundamental question that confronts us in solving the problem of maturity in cane is this: Can a joint once completely developed, i. e., attained a dry-leaf status, increase in sucrose concentration? The only way the question can be solved is by analyzing the same joint from time to time. The hand refractometer method is the only one available to us at present to make such a study. We have similar studies under progress already, but the results to date are too fragmentary to be reported upon. In these studies we puncture a joint at one point this time and the next time at another point well removed from this first puncture. After each puncture, we seal up the broken tissue with putty or plastic wood to minimize infection. We have been making observations at intervals of two months. We find that infection still spreads and, therefore, the number of observations that can be made on the same joint depends on the size of the joint. If the joint is small, the infection spreads so far that we cannot make another puncture without striking deteriorated tissue and, of course, as soon as we do this the readings become unreliable. On the other hand, if the joints are big we can make two or three punctures in each joint without running into trouble. There is every reason to believe that we may be able to improve our manner of extracting the juice and subsequent sealing up the wound by which tissue deterioration will be lessened if not eliminated. But even two punctures in the same joint at two-

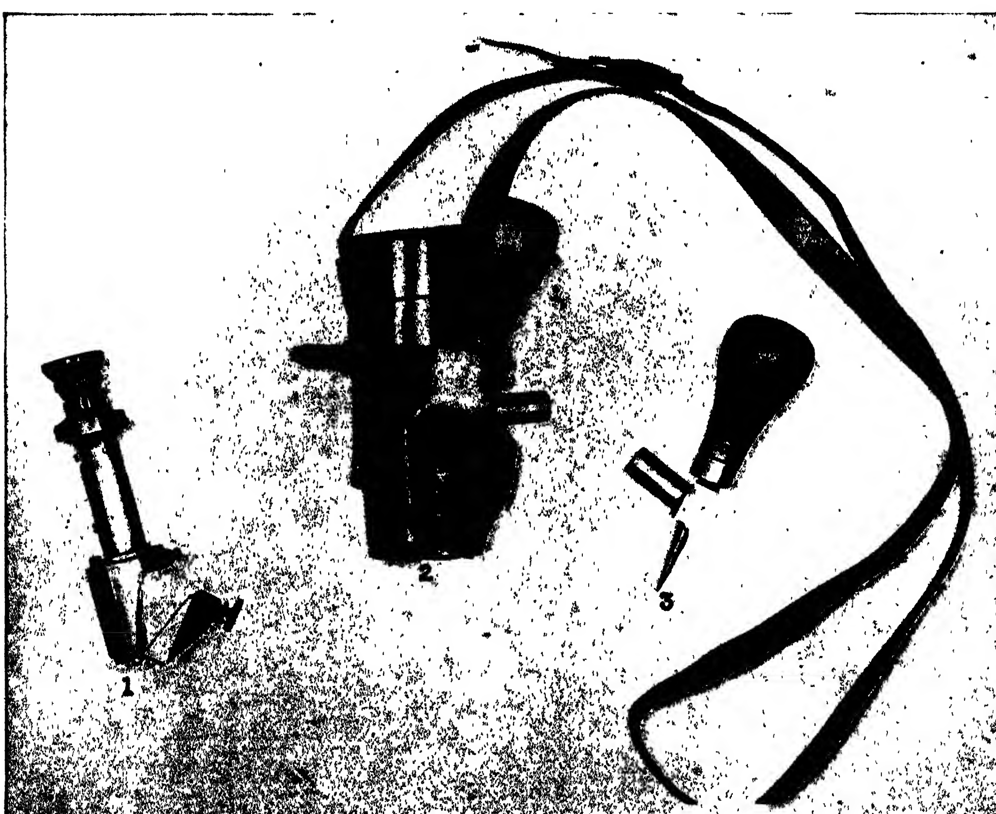


Fig. 3. The hand refractometer (1) and the punch juice sampler (3) are suitable equipment for obtaining a rapid and comparatively accurate analysis of the sucrose content of growing cane.

month intervals ought to tell us something and the data obtained so far appear to do so.

The brief account given here is merely to indicate the many uses to which this simple equipment can be put for the purpose of conveniently obtaining an insight into inner processes of cane life. There is little doubt that the future will see a great expansion of studies of this type, made possible for the first time by the equipment herein described.

III. Some Practical Uses for the "Punch Juice Sampler" and Hand Refractometer in the Cane Fields

A. Comparative Studies on Seedlings.

The figure for total solids in solution (Brix) as shown by the refractometer has been used by the Experiment Station since 1917 as an expression of sucrose content of seedlings which are in the preliminary stages of testing. It has provided a rapid means of securing information on this important quality where thousands of seedlings must be examined.

In taking a juice sample for the Brix reading on a seedling a composite sample consisting of the juice squeezed from the middle portion of the dry-leaf section of the stalk is collected from a specified number of stalks. In the preliminary trials at the Kailua substation and the Field Trial 1 tests at the Regional stations between one-half and all the stalks in the plot are sampled for the composite. In larger plots such as in the Field Trial 2 tests where many stalks are available for sampling, a large enough number is sampled to insure a composite which will be representative of the whole. This number is determined by the stalk-to-stalk variation found in the cane under test at the time of harvest, as explained in Section I of this paper.

The development of the punch sampler offers a rapid way for obtaining a juice sample of seedlings. It also gives the operator a good idea of the relative hardness of the seedlings as he works with them.

B. Preharvest Juice Sampling to Determine Relative Ripeness of Fields.

A recent publication from Java (4) tells of the use of a punch and refractometer similar to those illustrated in Fig. 3, as a means of obtaining preharvest juice samples on fields which are approaching maturity. The system evolved from these instruments is preferred to the one in vogue where whole stalks are cut from the field, because it allows for the sampling of many more stalks and the obtaining of a figure which more nearly approaches the true mean for the field.

In studying the ripening of a field of cane there are two sections of the cane stalk which should be considered separately, i. e., the mature section and the immature section. The mature section is the lower dry-leaf portion of the stalk and may be considered as that part of the stalk where sucrose storage is nearly at a maximum, and therefore an index of what the field is capable of yielding. The immature section includes the green-leaf part as well as the 6 to 8 joints immediately below the last adhering green leaf. For convenience these may be designated as "A," the mature section, and "B," the immature section.

In the process of ripening it is assumed that as either or both of the elements

Fig. 4. The relationship of the Brix at "A" (the mature section) to "B" (immature section) is a measure of the ripeness of the stalk of cane. Thus as "B" approaches "A" the stalk is nearing maximum maturity.

nitrogen and water become limiting, the vegetative growth of the cane is slowed down and therefore will allow a greater storage of energy in the form of sucrose. It is also assumed that the "B" section of the stalk will be influenced the most since it is here that there is a changing Brix.

The mature dry-leaf portion will not improve in sucrose content although the concentration of the quantity in solution may increase through the simple expedient of evaporation as the whole stalk loses moisture on drying out.

With these two premises in mind the ripeness of a field will not be the sucrose content of the stalks as a whole, but that of the upper "B" section in relation to the mature "A" section. Thus the ripeness can be expressed as:

$$\frac{\text{Brix of "B" section}}{\text{Brix of "A" section}} = \text{per cent ripeness of "B" section.}$$

The following data were collected from varieties in an experiment at Honolulu Plantation Company, two months before the scheduled harvest.

Cane 12 months old—irrigations every 15 days—25 stalks used for each sample —4 samples taken on each variety from different locations in the experiment.

Variety	Sample No.	Brix of Mature (Section A)	Brix of Immature (Section B)	Per cent Ripeness of Section B
P.O.J. 2878..........	2-a	22.0	17.3	80
	b	21.7	17.9	83
	c	22.2	18.1	81
	d	19.6	15.2	78
31-1389	3-a	18.4	14.9	81
	b	18.4	14.9	81
	c	19.4	14.8	76
	d	17.8	14.1	80
28-1234	1-a	17.4	13.1	76
	b	17.6	13.8	78
	c	17.6	13.0	74
	d	16.2	11.9	73

Note: The "d" samples were collected from a section of the experiment where all the varieties had made a greater vegetative growth than in other parts of the experiment. This has apparently been done at the expense of sugar storage for the Brix in the mature "A" section is lower in all cases.

It is interesting to note that ripeness of the "B" section is quite consistent within a variety, but differs among varieties.

In all preharvest juice sampling work the key to successful results lies in the careful selection of sampling stations which will give the best weighted average for the whole field. W. Wolters (5, pp. 413-14) stresses this point and specifies one station for approximately every 15 acres in a field. Where conditions are quite variable this ratio might be decreased to insure greater accuracy.

C. *An Aid in Determining the Profitable Height for Topping the Cane in the Harvesting Field.*

It is a common practice on plantations to top low in the early part of the harvesting season and higher as the summer months approach. J. D. Bond (1) sup-

ports this practice with an extensive set of data collected at Ewa Plantation Company. With this differential in height of maturity in the cane stalk as established by long experience as well as by experimental evidence, it may be assumed that there are minor variations of maturity in the green-leaf portion of the stalk from field to field or from variety to variety which would be profitable to determine. The punch sampler and refractometer offer rapid means for making such a determination.

A conservative calculation will illustrate the value of each foot of stalk of H 109 cane in terms of tons cane per acre:

24,000 stalks per acre — one foot of cane weighs .50 pound.
24,000 $\times$ .5 = 12,000 pounds, or six tons per acre.

The question of whether these six tons of cane should be saved resolves itself into the relationship of a number of factors with one another, i. e., (1) sucrose content of this cane, (2) price of sugar, and (3) the various costs controlled by cane weight such as harvesting, milling, and long-term contracts.

The relation of Brix to per cent recoverable sugar is not the same in the immature green-leaf portion of the stalk as in the mature dry-leaf portion of the

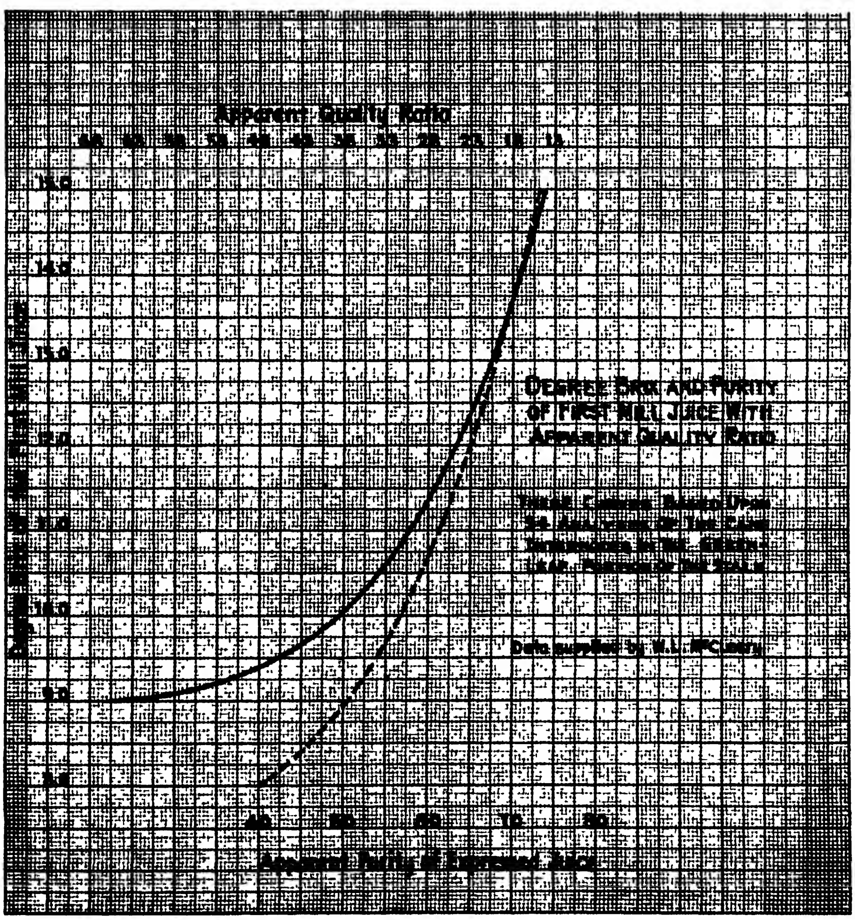


Fig. 5. Interpolating for apparent Quality Ratio from Brix readings made in the green-leaf portion of a stalk should be done on this curve since it is based upon analyses from this region where the purity is low.

stalk for in this area there is concentrated a large proportion of non-sucrose solids. The result is that as the growing point is approached the purity becomes lower. A correlation curve (Fig. 5) based upon the analysis of juice from internodes within the green-leaf section of the stalk shows this property of purity to decrease in this region as the Brix becomes lower.

A few drops of juice from the upper internodes of a number of stalks chosen at random in the harvesting field will give a fair idea as to how far ripeness is extending into the green-leaf portion of the stalk. The apparent Quality Ratio can be roughly interpreted by interpolating the Brix reading on the curve shown in Fig. 5.

IV. Use of "Punch Juice Sampler" and Hand Refractometer in Formosa.

In Formosa, factory operators buy the cane from small planters. The sugar cane is therefore a merchandise and its value is usually reckoned on the basis of weight. Consequently the buyers are greatly concerned with the quality of the cane, whereas the farmers are interested in the weight.

The good quality of cane is maintained by setting a limit on the amount of fertilizer to apply, by preharvesting tests, and by eliminating trash, dirt, and sour stalks.

To determine just when to cut a field of sugar cane, a man armed with a punch juice sampler and a hand refractometer, enters the field and selects sound stalks from different points along a diagonal line of a field. Fields in Formosa range in size from about a quarter of an acre to three or four acres. Each stalk is tested separately at three different points, about a quarter-way up from the ground, in the middle, and at a top joint near the node to which the seventh or the eighth open leaf attaches itself to the stalk. Brix only is read. At first the top shows a low Brix, but as the season advances the readings equalize, and then the cane is thought to be ripe. The tests are made approximately once a month, beginning the end of November.

The harvesting usually starts in January and ends in April.

Even a small field may be divided into different parts if it shows differences with respect to: growth, amount of lodging, extent of damage, and the degree of ripeness. These are then tested separately.

A mill operator may have ten or more men testing cane throughout the area from which the cane is purchased, and whenever the actual recovery figure fails to come up to the expected figure, an examiner is sent to the field immediately to decide whether or not to discontinue the harvesting operation and to study the causes of the disagreement between the previous study and the actual recovery at the mill. The reasons usually found for the disparity are:

Error in the preharvesting tests.
Wind damage to the leaves.
Sudden insect and disease attacks.
Flooding of the field.

Selective harvesting is practiced even in small fields, disregarding almost entirely the convenience of the harvesting gang.

Literature Cited

(1) Bond, J. D., 1928. The topping of cane at harvest. The Hawaiian Planters' Record, Vol. XXXII, pp. 19-22.

(2) Das, U. K., 1934. The sugar cane plant—a study of millable cane and sucrose formation. The Hawaiian Planters' Record, Vol. XXXVIII, pp. 33-94.

(3) Denny, F. E., 1922. Formulas for calculating number of fruits required for adequate sample for analysis. The Botanical Gazette, Vol. LXXIII, pp. 44-57.

(4) Levert, L., van der Woude, C. A. A., and van Dillewijn, C., 1934. Bepaling der bemonsteringsdichtheid van een gegeven aanplant en toepassing der refractometrische methode van rijpheidsbepaling in de practijk. English abstract in Facts About Sugar, Vol. XXIX, pp. 167 and 243, 1934.

(5) Wolters, W., 1931. Determination of the ripeness of cane by means of preharvest sampling. The Hawaiian Planters' Record, Vol. XXXV, pp. 411-418.

A Pot Experiment With Cane Grown in the Same Soil But Under Different Climatic Conditions

By U. K. Das

The present paper gives the results of a preliminary experiment designed to study the effect of climatic environment on cane growth when all other growth conditions including the soil are kept constant.

The experiment was carried on simultaneously at the main Experiment Station at Makiki, and at the substation at Manoa. These stations possess climatic characteristics which are entirely different from each other, but each station is representative of large cane areas in these Islands. At Makiki the mean annual maximum temperature is about 85° (*), total annual rainfall about 40 inches, and the cane here is grown entirely by irrigation. The mean annual maximum temperature at Manoa is about 79°, total annual rainfall about 160 inches, and the cane here is normally grown without irrigation, although for the purpose of this experiment the cane was occasionally irrigated when rainfall was deficient in any period. The Manoa substation suffers from the further disadvantage of being subject to strong winds and to being cast in shadow in the afternoon due to the intervention of a mountain range. The climatic conditions at Makiki would thus be typical of irrigated areas in Oahu, while that of Manoa of some areas in Hawaii.

The cane was planted in tubs. Each tub measured two feet on each side and two feet in depth, giving a capacity of eight cubic feet of soil. All the tubs were filled with good Makiki soil, which is rich in phosphates and potash. Manoa soil on the other hand is very deficient in both of these nutrients. Six of these tubs containing the Makiki soil were transported to the Manoa substation and placed in a favorable location. Six similar tubs were kept in Makiki.

On August 9, 1933, three tubs in each location were planted with uniform seedpieces of P.O.J. 2878 and P.O.J. 36, respectively, containing equal number of eyes. Two varieties were used so that the differential climatic adaption, if any, could also be studied.

The tubs were fertilized on the same day at both the locations. The fertilizer was a mixture of N, P_2O_5, and K_2O and was applied at three different times. At Makiki the tubs were always kept well watered, at Manoa occasional irrigation was applied to make up for the deficiency of rainfall at any period. Thus, as far as possible, all the conditions of growth were equal in both places with the exception of those that were climatic, namely: temperature, light, wind, etc.

The test was harvested on August 1, 1934, at the age of approximately 12 months. Tables I and II give the yield of green matter. Fig. 1 shows the stand

(*) In comparison with the U. S. Weather Bureau's Honolulu Office record of an annual mean maximum temperature of about 80° F., the Makiki average of 85° would appear too high. This might be due to the influence of the particular spot where the thermometer is housed at Makiki, as the thermometer itself has been found to be correct.

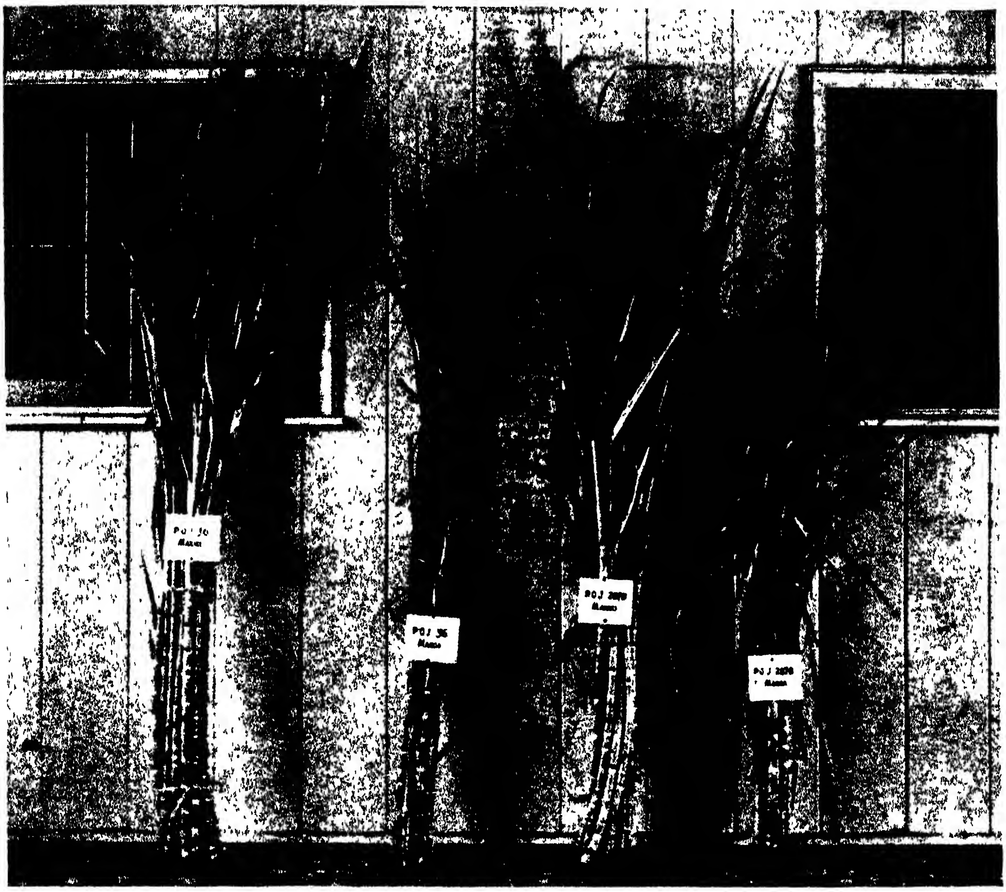


Fig. 1. Showing the differences in growth of P.O.J. 2878 and P.O.J. 36 at Manoa and Makiki. The canes were in large concrete tubs containing Makiki soil only. These striking differences that are undoubtedly due to environmental influences only, would suggest that the soil differences have little influence on yields.

of cane obtained from typical tubs in this test. Table III shows the quality of juice.

TABLE I

Yield in Pounds

MANOA SUBSTATION

	Green Weight	Millable Cane Weight	No. of Millable Sticks	Dry Trash
P.O.J. 2878:				
Tub 1	10.06			
Tub 2	12.81			
Tub 3	12.19			
Total Weight	35.06	16.56	37	6.25
P.O.J. 36:				
Tub 1	14.50			
Tub 2	14.31			
Tub 3	12.39			
Total Weight	41.20	22.19	46	5.44

MAKIKI STATION

P.O.J. 2878:				
Tub 1	28.44		22	4.75
Tub 2	26.19		18	4.19
Tub 3	30.13		19	4.50
Total Weight	84.76	49.25	59	13.44
P.O.J. 36:				
Tub 1	32.39		29	
Tub 2	29.25		24	
Tub 3	38.00		24	
Total Weight	99.64	63.39	77	12.25

TABLE II

Relative Yield Due to Varieties and to Locations

P.O.J. 36 / P.O.J. 2878	Manoa	Makiki
Ratio of green weight	1.175	1.176
Ratio of millable cane	1.34	1.28
Ratio No. of sticks	1.24	1.31
Ratio dry trash	0.87	0.91

Ratio Manoa / Makiki	P.O.J. 2878	P.O.J. 36
Total green weight	2.42	2.42
Total millable cane	2.97	2.86
Total No. of sticks	1.59	1.67
Total dry trash	2.15	2.25

TABLE III

Quality of Juice

MANOA	P.O.J. 36	P.O.J. 2878
Sucrose	17.38	15.37
Glucose	0.36	0.57
Gravity Purity	89.96	87.43
Q. R.	7.66	9.01

MAKIKI	P.O.J. 36	P.O.J. 2878
Sucrose	18.37	17.79
Glucose	0.24	0.48
Gravity Purity	90.81	89.49
Q. R.	7.30	7.64

Yield of Cane:

The results show that both varieties yielded more green matter at Makiki than at Manoa and by exactly the same relative amount. P.O.J. 36 was 2.42 times better at Makiki than at Manoa, as was P.O.J. 2878. The climatic effects on the yields of the two varieties were also very nearly the same in the matter of millable cane, number of sticks, and dry trash. This striking difference in the yields of two varieties at Makiki and Manoa would strongly suggest the preponderance of climatic effects over other growth conditions. Such differences when encountered on different areas of plantations would often be attributed in large part to soil conditions.

Table II also shows that P.O.J. 36 yielded just as much more than P.O.J. 2878 at Manoa as it did at Makiki. In other words, in the matter of green matter, number of sticks, etc., there can be seen no differential adaptability of these two varieties to the climatic differences. This comes somewhat as a surprise, because it was felt from experience that P.O.J. 2878 might do relatively better at Makiki than at Manoa.

Juice Quality:

In the matter of juice quality Makiki environment appears to be considerably better than Manoa. This is quite in agreement with the results of our previous weather studies wherein it was shown that a location with wider range of daily temperature usually gave better juices than another where the daily range was much smaller. It would also appear from the results that P.O.J. 36 was better suited to make good juice at Manoa than at Makiki. There was a difference due to environment of more than two per cent of sucrose in P.O.J. 2878, while this difference was only one per cent in the case of P.O.J. 36.

Climatic Factors:

It is not possible to precisely evaluate the magnitude of differences of all the climatic factors. We have, however, sunlight data which show that Makiki had approximately 40 per cent more sunlight than Manoa. Effective temperature as measured by day-degrees (base line 70° F. of mean maximum temperature) was 5663 at Makiki and 3477 at Manoa, or a difference of 64 per cent in favor of Makiki (this difference would be much greater if a higher base line were used to compute day-degrees). We have no data on wind which is a factor of considerable importance in this present study as on several occasions the cane at Manoa was very badly damaged by strong winds. During the period of the experiment 131 inches of rain fell at Manoa.

Summary:

This experiment makes specific measurements of different aspects of growth of two varieties of cane as influenced by climatic differences only; the soil factor being held constant. P.O.J. 36 and P.O.J. 2878 appear to respond to the climatic factors in the same manner and to the same extent. Makiki climate is far better than Manoa climate in the matter of yield and quality. P.O.J. 36 appears to be better adapted to Manoa in the matter of quality than P.O.J. 2878.

In conclusion, the preliminary nature of the experiment must be emphasized. The results given here are of definite interest only as far as they point to the desirability of further research along similar lines.

The Experiment Station has already under way a more elaborate experiment of this kind.

Plantation Fertilizer Practices

By D. S. Judd and R. J. Borden

A paper entitled "Present Fertilizer Practices on the Sugar Plantations of the Hawaiian Islands" was presented in 1924 at the third annual meeting of the Association of Hawaiian Sugar Technologists by J. A. Verret. This paper gave the compiled answers to questionnaires which had been circulated among the various plantations, and included a discussion of the mixed fertilizers used, their composition, and their relative merits. At the 1928 meeting of the A. H. S. T. an article was presented by W. W. G. Moir on "Soils and Fertilizers" which gave a general survey of the plantation fertilizer practices of that date. Another article of a similar nature which appeared the following year was written by G. R. Stewart, and included a graphical presentation intended to show the relationship of the time of application of fertilizers to the respective starting and harvesting dates.

"Present Day Fertilizer Practices" by H. P. Agee, which was presented at the 1931 meeting of the Hawaiian Sugar Planters' Association, presented a clear and simple graphic form for recording different fertilizer practices, which has been used since that time in the presentation of data of this nature. It was used in 1932 at the annual meeting of the H. S. P. A. by J. A. Verret in his article "The Year's Developments in Fertilizer Practices and Economies." It is used again in this paper which has been prompted by a suggestion that these printed fertilizer schedules be kept up-to-date, in order that the various changes and trends may be recorded and followed by those who are interested.

We acknowledge the cooperation of the varicus plantation men, and the island representatives of the Experiment Station who assisted us in the gathering of the data for this present work.

The principal general changes noted are the wider use of simple fertilizers, and the trend toward the differential fertilization of fields from the results of analytical soil analyses and experimental work.

In 1932, four plantations were using simples alone with no mixed fertilizers. We note that this year ten plantations are following this practice. Five plantations are using more simples than formerly with no increase in the number of mixed fertilizers used. On the other hand, we note that nine plantations are using more fertilizer mixtures than in 1932, but of these, five are also using more simples. Six plantations indicate no change in the types of fertilizers used since the 1932 schedule.

It will be noted that more of the plantations are fertilizing along the lines of the actual needs of the fields as indicated by field experiments and the results of chemical analyses and pot studies. The idea of a general practice for the whole plantation is fading out; individual field fertilizer needs are being studied, and further, spot fertilization within the individual fields is being practiced.

COMPARISONS OF FERTILIZERS USED IN 1932 AND 1934

PLANTATIONS	1932 MIXED FERTILIZER	1932 SIMPLES	1934 MIXED FERTILIZER	1934 SIMPLES
HAWAII				
HUTCHINSON	B-24	Ammo. Sul.		Mur. Pot. Ammo. Phos. Ammo. Sul.
HAWAIIAN AGR.	B-21	Ammo. Sul.	B-21	Ammo. Sul. Superphos.
OLAA	A-11 A-12		A-11 A-12	
WAIAKEA	M.F. 10-5-20		M.F. 6-10-25 M.F. 10-5-20	Ammo. Sul.
HILO	B-19	Ammo. Sul.	B-19	Ammo. Sul.
ONOMEA	B-19	Ammo. Sul.	B-19	Ammo. Sul. Ammo. Phos. Chile Pot. Nit. Mur. Pot.
PEPEEKEO	B-19	Ammo. Sul.	B-19	Ammo. Sul. Treble Super Chile Pot. Nit.
HONOMU	B-17	Ammo. Sul.	B-17	Ammo. Sul.
HAKALAU	B-17	Ammo. Sul.	B-25	Chile Pot. Nit.
LAUPAHOEHOE	M.F. 11-8-20	Ammo. Sul.	M.F. 11-8-20	Ammo. Sul.
KAIWIKI	M.F. 15-9.5-15	Ammo. Sul.		Chile Pot. Nit. R. R. Phos.
HAMAKUA	M.F. 12.4-9.6-18	Ammo. Sul.	M.F. 14.25-12.25-14.5	Ammo. Sul.
PAAUHAU	P-1	Ammo. Sul.	P-2	Ammo. Sul.
HONOKAA	A B C D } Home Mixed		A B C D } Home Mixed	
KOHALA	NOT REPORTED			Ammo. Sul. Ammo. Phos. Nit. Lime Mur. Pot. Nit. Pot.
UNION	M.F. 7.5-15.5-26	Ammo. Sul.	M.F. 9.3-13.3-20	Ammo. Sul.
KAUAI				
KILAUEA	K-8	Ammo. Sul.	K-8	Ammo. Sul. Chile Pot. Nit.
LIHUE	A-16	Ammo. Sul. Urea Nit. Potash	A-20	Ammo. Sul. Chile Pot. Nit.
GROVE FARM	P.S. 5A	Ammo. Sul. R.R. Phos. Superphos.	P.S. 5A P.S. 5AX	Ammo. Sul. R. R. Phos.
KOLOA	A-16 X-50		A-16 A-20 X-50A	Ammo. Sul. Chile Pot. Nit.
McBRYDE	McB.-A	Ammo. Sul. Ammo. Phos. R.R. Phos. Mur. Pot.		Ammo. Sul. Ammo. Phos. R. R. Phos. Mur. Pot.
HAWAIIAN SUGAR	H.S.-2	Ammo. Sul. Nit. Soda	H.S.-2 H.S.-3 H.S.-4	Ammo. Sul. Nit. Soda Mur. Pot. Chile Pot. Nit.
WAIMEA	A-17	Ammo. Sul. Nit. Pot.	A-17 X-50A	Ammo. Sul. Nit. Soda
KEKAHA	A-17	Ammo. Sul. Nit. Pot.	A-17 X-50A X-56	Ammo. Sul. Nit. Soda

COMPARISONS OF FERTILIZERS USED IN 1932 AND 1934—Continued

PLANTATIONS	1932 MIXED FERTILIZER	1932 SIMPLES	1934 MIXED FERTILIZER	1934 SIMPLES
MAUI				
PIONEER	A-17	Ammo. Sul. Nit. Pot.	A-17 A-19 X-35	Ammo. Sul. Ammophos. A Nit. Pot. Chile Pot. Nit.
WAILUKU	W-1	Ammo. Sul.		Ammo. Sul. Ammo. Phos. Mur. Pot.
H. C. & S. CO.	G-1 G-2 G-3	Ammo. Sul. Nit. Soda	G-2	Ammo. Sul. Nit. Soda Ammo. Phos.
M. A. CO.		Ammo. Sul. Ammo. Phos.		Ammo. Sul. Ammo. Phos.
OAHU				
WAIMANALO	Nalo - "C"	Ammo. Sul. Ammo. Phos. Mur. Pot.		Nit. Soda DiAmmo. Phos. R. R. Phos. Chile Pot. Nit.
KAHUKU		Ammo. Sul. Superphos. Mur. Pot.		Ammo. Sul. Ammo. Phos. Mur. Pot.
WAIALUA		Ammo. Sul. Superphos. Mur. Pot.		Ammo. Sul. Ammo. Phos. Superphos. Mur. Pot.
WAIANAE	A-15	Ammo. Sul. Urea Nit. Pot.	A-15 A-21	Ammo. Sul. Chile Pot. Nit. Urea/Nit. Pot.
EWA		Ammo. Sul.* Nit. Soda Nit. Pot. Mur. Pot.		Ammo. Sul. * Nit. Lime Chile Pot. Nit. Mur. Pot.
OAHU	A-14	Ammo. Sul. Nit. Soda	A-14 A-15	Ammo. Sul. Nit. Soda
HONOLULU	F-1 F-2 F-3 F-4	Ammo. Sul.	A, B, C, D, E, F, G, H — Home Mixed	Ammo. Sul. Nit. Lime

* Ewa — 1st Ammo. Sul. application may be Ammo. Phos. if field requires P_2O_5.

Examples of many of the specific fertilizer schedules for the plantations are submitted herewith:

List of Abreviations Used

A.P. = Ammonium Phosphate.

A.P.A. = Ammonium Phosphate "A."

A.S. = Ammonium Sulfate.

C.P.N. = Chile Potash Nitrate.

Di.AP = Diammonium Phosphate.

H.G. = High Grade.

Mol.Ash = Molasses Ash.

M. F = Mixed Fertilizer.

M.P. = Muriate Potash.

N.L. = Nitrate of Lime.

N.P. = Nitrate of Potash.

N.S. = Nitrate of Soda.

R.R.P. = Raw Rock Phosphate.

Super = Superphosphate

T.S.P. = Treble Superphosphate.

A-16, K-8, P.S.5AX = Trade names of mixed fertilizer.

Wks. = Weeks.

Mos. = Months.

Appl. = Application.

KEY

Kind of Fertilizer	N	P_2O_5	K_2O
	— %	— %	— %
—#P.A.	—#P.A.	—#P.A.	—#Per Acre

HUTCHINSON S.P. CO.

Fields very deficient in P_2O_5 and K_2O

①	A.P. / 500	13 / 65	48 / 240		Immediately after start
②	A.S. / 200	20.5 / 41			2½ months after ①
	M.P. / 218¾			60 / 131	”
③	A.S. / 300	20.5 / 61.5			2½ months after ②
	M.P. / 250			60 / 150	”
④	A.S. / 200	20.5 / 41			3 months after ③
	Total	208.5	240	281	

Fields with good supply of P_2O_5 and K_2O

①	A.P. / 218¾	13 / 28.5	48 / 105		Immediately after start
	A.S. / 200	20.5 / 41			(not applied in plant crop)
②	A.S. / 200	20.5 / 41			2½ months after ①
③	A.S. / 300	20.5 / 61.5			2 months after ②
	M.P. / 166⅔			60 / 100	”
④	A.S. / 300	20.5 / 61.5			3 months after ③
	Total	233.5	105	100	

Fields moderately deficient in P_2O_5 and K_2O

①	A.P. / 312½	13 / 40.5	48 / 150		Immediately after start
②	A.S. / 300	20.5 / 61.5			2½ months after ①
③	A.S. / 300	20.5 / 61.5			2½ months after ②
	M.P. / 250			60 / 150	”
④	A.S. / 300	20.5 / 61.5			3 months after ③
	Total	225	150	150	

Fields very high in P_2O_5 and K_2O

①	A.S. / 300	20.5 / 61.5			Immediately after start
②	A.S. / 300	20.5 / 61.5			2 months after ①
③	A.S. / 300	20.5 / 61.5			2 months after ②
④	A.S. / 200	20.5 / 41			3 months after ③
	Total	225.5			

HAWAIIAN AGRI. CO.

Plant cane - all fields

①	B21 / 250	9 / 22.5	20 / 50	10 / 25	With seed
	Super / 375		20 / 75		
②	B21 / 375	9 / 33.75	20 / 75	10 / 37.5	No regular intervals when thought advisable
③	A.S. / 300	20.5 / 61.5			”
④	B21 / 375	9 / 33.75	20 / 75	10 / 37.5	”
⑤	A.S. / 450	20.5 / 92.25			”
	Total	243.75	275	100	

Ratoons-all fields

①	B21 / 375	9 / 33.75	20 / 75	10 / 37.5	No regular intervals when thought advisable
	Super / 375		20 / 75		”
②	A.S. / 300	20.5 / 61.5			”
③	B21 / 625	9 / 56.25	20 / 125	10 / 62.5	”
④	A.S. / 450	20.5 / 92.25			”
	Total	243¾	275	100	

OLAA SUGAR CO.

Olaa - Pahoa - Kapoho Sections

①	A-11 / 300	15 / 45	7 / 21	15 / 45	All fertilizer is on 9-12 months after harvest
②	A-11 / 400	15 / 60	7 / 28	15 / 60	”
③	A-11 / 400	15 / 60	7 / 28	15 / 60	”
④	A-11 / 300	15 / 45	7 / 21	15 / 45	”
	Total	210	98	210	

Mountain View Section

①	A-12 / 300	15 / 45	5 / 15	18 / 54	All fertilizer is on 9-12 months after harvest
②	A-12 / 400	15 / 60	5 / 20	18 / 72	”
③	A-12 / 400	15 / 60	5 / 20	18 / 72	”
④	A-12 / 300	15 / 45	5 / 15	18 / 54	”
	Total	210	70	252	

WAIAKEA MILL CO.

All cane on average land 1935 crop					
①	A.S. / 400	20.5 / 82			6-12 wks. after harvest
②	M.F. / 625	10 / 62.5	5 / 31.25	20 / 125	16-24 "
③	M F / 625	10 / 62 5	5 / 31 25	20 / 125	32-40 "
Total		207	62.5	250	

All cane, average land 1936 crop					
①	A.S. / 400	20.5 / 82			6-12 wks. after harvest
②	M.F. / 1000	6 / 60	10 / 100	25 / 250	16-24 "
③	A.S. / 400	20.5 / 82			32-40 "
Total		224	100	250	

HILO SUGAR CO

①	B19 / 500	7.5 / 37.5	15 / 75	25 / 125	2 weeks of age
②	B19 / 500	7.5 / 37.5	15 / 75	25 / 125	8 "
③	A.S. / 300	20.5 / 61.5			16 "
④	A S. / 300	20 5 / 61.5			20 "
Total		198	150	250	

ONOMEA SUGAR CO.

Short ratoons					
①	B19 / 625	7 5 / 46.8	15 / 93.7	25 / 156¼	1st. hoeing
②	B19 / 625	7.5 / 46.8	15 / 93 7	25 / 156¼	2 months after ①
③	A.S. / 400	20.5 / 82			3 months after ②
Total		175.6	1874	312.5	

Mauka Poor soil 1936 crop					
①	A.P. / 375	10 / 37.5	49 / 183.7		1st hoeing in plant On stubble in ratoons
②	M.P / 250			60 / 150	2 months after ①
③	C.P.N. / 500	15 / 75		14 / 70	2 months after ②
④	C P.N / 500	15 / 75		14 / 70	2months after ③
Total		187.5	183.7	290	

Makai Good soils 1936 crop					
①	A.P. / 250	10 / 25	49 / 122.5		1st. hoeing in plant On stubble in ratoons
②	M P. / 250			60 / 150	2 months after ①
③	C.P.N. / 500	15 / 75		14 / 70	2 months after ②
④	C P.N. / 500	15 / 75		14 / 70	2 months after ③
Total		175	122.5	290	

PEPEEKEO SUGAR CO.

Plant and Ratoons 1935 crop

(1)	B 19	7.5	15	25	1 month after start
	500	37.5	75	125	
(2)	A.S.	20.8			1½-2 months after (1)
	300	62.4			
(3)	B 19	7.5	15	25	2-2½ months after (2)
	375	28.12	56¼	93¾	
(4)	A.S.	20.8			About 2 mos. after (3)
	300	62.4			
	Total	190.42	131¼	218¾	

Plant and Ratoons 1936 crop

(1)	T.S.P.		40.5		1 month after start
	500		202.5		
(2)	C.P.N.	14.7		17.2	1½-2 months after (1)
	700	103		120.4	
(3)	C.P.N.	14.7		17.2	2-2½ months after (2)
	700	103		120.4	
	Total	206	202.5	240.8	

HONOMU SUGAR CO.

Ratoons-above 750' elevation

(1)	B-17	7.5	7.5	25	At age of 1 month
	500	37.5	37.5	125	
(2)	A.S.	20.5			1 month after (1)
	300	61.5			
(3)	B-17	7.5	7.5	25	(before hilling) 2 months after (2)
	500	37.5	37.5	125	
(4)	A.S.	20.5			Within 5 months of start
	300	61.5			
	Total	198	75	250	

Ratoons-below 750' elevation

(1)	B-17	7.5	7.5	25	At age of 1 month
	500	37.5	37.5	125	
(2)	A.S.	20.5			1 month after (1)
	400	82			
(3)	B-17	7.5	7.5	25	Within 5 months of start
	500	37.5	37.5	125	
	Total	157	75	250	

Plant cane at all elevations

(1)	B-17	7.5	7.5	25	At age of about 2 mos.
	250	18.75	18.75	62.5	
(2)	A.S.	20.5			1 month after (1)
	300	61.5			
(3)	B-17	7.5	7.5	25	2 months after (2)
	375	28⅛	28⅛	93¾	
(4)	B-17	7.5	7.5	25	(before hilling) About 2 mos. after (3)
	375	28⅛	28⅛	93¾	
(5)	A.S.	20.5			Within 7-8 mos. of start
	300	61.5			
	Total	198	75	250	

HAKALAU PL. CO.

(1)	B-25	10	7.5	25	About 2 months after harvest
	500	50	37.5	125	
(2)	B-25	10	7.5	25	5 months after harvest
	625	62.5	46.87	156¼	
(3)	C.P.N.	15		14	9 " " "
	500	75		70	
	Total	187.5	84.37	351¼	

LAUPAHOEHOE S. CO.

(1)	M.F.	11	8	20	About 1 month after harvest
	375	41.25	30	75	
(2)	M.F.	11	8	20	(after hoeing) 1 month after (1)
	375	41.25	30	75	
(3)	A.S.	20.5			(after hoeing) 1 month after (2)
	200	41			
(4)	M.F.	11	8	20	4-6 months old cane
	375	41.25	30	75	
(5)	A.S.	20.5			Late fall or spring application
	300	61.5			
	Total	226¼	90	225	

KAIWIKI SUGAR CO.

Mauka - above 1250' (Maximum)

①	R.R.P. / 1350		37 / 500		With seed
②	C.P.N. / 500	14.8 / 75		14.2 / 75	Within first 2 months
③	C.P.N. / 500	14.8 / 75		14.2 / 75	June - August
④	C.P.N. / 350	14.8 / 50		14.2 / 50	Feb. - March
	Total	200	500	200	

Mauka-above 1250' (Minimum)

①	R.R.P. / 400		37 / 150		With seed
②	C.P.N. / 450	14.8 / 65		14.2 / 65	Within first 2 months
③	C.P.N. / 450	14.8 / 65		14.2 / 65	June - August
④	C.P.N. / 350	14.8 / 50		14.2 / 50	Feb. - March
	Total	180	150	180	

Makai - below 1200' (Maximum)

①	R.R.P. / 400		37 / 150		With seed
②	C.P.N. / 700	14.8 / 100		14.2 / 100	Within first 2 months
③	C.P.N. / 500	14.8 / 75		14.2 / 75	June - August
④	C.P.N. / 350	14.8 / 50		14.2 / 50	Feb. - March
	Total	225	150	225	

Makai - below 1200' (Minimum)

①	R.R.P. / 300		37 / 100		With seed
②	C.P.N. / 450	14.8 / 65		14.2 / 65	Within first 2 months
③	C.P.N. / 450	14.8 / 65		14.2 / 65	June - August
④	C.P.N. / 350	14.8 / 50		14.2 / 50	Feb. - March
	Total	180	100	180	

HAMAKUA MILL CO.

①	M.F. / 600	14.25 / 85.5	12.25 / 73.5	14.50 / 87	6 weeks of age
②	M.F. / 600	14.25 / 85.5	12.25 / 73.5	14.50 / 87	4-6 months of age
③	A.S. / 200	21 / 42			10-11 months of age
	Total	213	147	174	

PAAUHAU S. P. CO.

Unirrigated

①	A.S. / 400	20.8 / 83			As soon as possible
②	P-2 / 416	9.6 / 40	19.2 / 80	19.2 / 80	2 months after ①
③	A.S. / 400	20.8 / 83			2 months after ②
	Total	206	80	80	

Irrigated area started May to August

①	A.S. / 800	20.8 / 166			As soon as possible after harvesting
②	P-2 / 416	9.6 / 40	19.2 / 80	19.2 / 80	
	Total	206	80	80	

HONOKAA SUGAR CO.

Fields above Lower Ditch

①	A / 750	15.26 / 114.5	13.44 / 100.8	14.91 / 111.8
②	A / 750	15.26 / 114.5	13.44 / 100.8	14.91 / 111.8
	Total	229	201.6	223.6

Fields between Lower Ditch and R.R.

①	B / 750	15.47 / 116	9.13 / 68.5	15.19 / 114
②	B / 750	15.47 / 116	9.13 / 68.5	15.19 / 114
	Total	232	137	228

Fields below Railroad

①	C / 900	12.48 / 112.3	6.99 / 63	11.93 / 107.4
②	C / 900	12.48 / 112.3	6.99 / 63	11.93 / 107.4
	Total	224.6	126	214.8

Fields below Railroad (alternate)

①	D / 750	15.66 / 117.5	7.47 / 56	14.91 / 111.8
②	D / 750	15.66 / 117.5	7.47 / 56	14.91 / 111.8
	Total	235	112	223.6

Time of application for the above

<u>If cane is started in Feb. or March</u>

① As soon as practical
② Follows close upon ①

<u>If cane is started - April to August</u>

① and ② combined in one dose, as soon as practical

<u>If cane is started after August</u>

① Applied as soon as practical
② In Spring

KOHALA SUGAR CO.

Unirrigated - Nitrogen only

1	N.L. / 300	15 / 45			4-6 weeks of age
2	N.L. / 300	15 / 45			12-14 " "
3	N.L. / 300	15 / 45			20 " "
4	N.L. / 300	15 / 45			30 " "
	Total	180	—	—	

Irrigated - Nitrogen only

1	A.S. / 200	20.8 / 42			4-6 weeks of age
2	A.S. / 300	20.8 / 62			12-14 " "
3	A.S. / 350	20.8 / 73			18-20 " "
	Total	177	—	—	

Unirrigated - Phosphates omitted

1	N.L. / 300	15 / 45			4-6 weeks of age
2	N.P / 250	13.2 / 31		44.2 / 112	12-14 " "
3	N.L. / 300	15 / 45			20 " "
4	N.L. / 400	15 / 60			30 " "
	Total	181	—	112	

Irrigated - Phosphates omitted

1	A.S / 200	20.8 / 42			4-6 weeks of age
2	M.P. / 200			58.5 / 117	12-14 " "
3	A.S / 300	20.8 / 62			12-14 " "
4	A.S. / 350	20.8 / 73			18-20 " "
	Total	177	—	117	

Unirrigated - Complete Fertilizer

1	A.P."A" / 250	10.7 / 27	49 / 123		(If plant - with seed) 2-4 weeks of age
2	N.P. / 250	13.2 / 31		44.2 / 112	10 " "
3	N.L / 300	15 / 45			20 " "
4	N.L. / 500	15 / 75			30 " "
	Total	178	123	112	

Irrigated - Complete Fertilizer

1	A.P."A" / 250	10.7 / 27	49 / 123		(If plant - with seed) 2-4 weeks of age
2	M.P. / 200			58.5 / 117	10 " "
3	A.S / 200	20.8 / 42			10 " "
4	A.S. / 500	20.8 / 104			18-20 " "
	Total	173	123	117	

Irrigated - Short crops - Nitrogen only

1	A.S. / 200	20.8 / 42			4-6 weeks of age
2	A.S. / 400	20.8 / 83			12-14 " "
	Total	125	—	—	

UNION MILL & PL. LTD.

Makai - below Gov't. Road

1	H.G. / 375	9.3 / 35	13.3 / 50	20 / 75	1 month after harvest
2	A.S. / 400	20.5 / 82			3 months " "
3	A.S. / 300	20.5 / 61			10 " " "
	Total	178	50	75	

Mauka - Central - above Gov't. Road

1	H.G. / 375	9.3 / 35	13.3 / 50	20 / 75	1 month after harvest
2	A.S. / 400	20.5 / 82			3 months " "
3	A.S. / 200	20.5 / 41			10 " " "
	Total	158	50	75	

KILAUEA S.P. CO.

Unirrigated cane other than Uba

①	K-8 / 750	4.5 / 33¾	26.6 / 199.5	14.9 / 111¾	Right after harvest
②	C.P.N. / 300	13 / 39		14 / 42	4-6 wks. after ①
③	C.P.N. / 325	13 / 42¼		14 / 45.5	6 wks. after ②
Total		115	199.5	199¼	

Irrigated cane other than Uba

①	K-8 / 750	4.5 / 33¾	26.6 / 199.5	14.9 / 111¾	With seed
②	A.S. / 250	20.5 / 51¼			6 weeks after ①
③	A.S. / 250	20.5 / 51¼			8 " " ②
④	A.S. / 200	20.5 / 41			4 " " ③
Total		177¼	199.5	111¾	

Uba cane ratoons

①	K-8 / 500	4.5 / 22.5	26.6 / 133	14.9 / 74.5	After harvest
②	A.S. / 200	20.5 / 41			1 month after ①
Total		63.5	133	74.5	

LIHUE PL. CO.

Mauka lands

①	A-20 / 800	6.25 / 50	31.25 / 250	17.75 / 142	At start
②	A.S. / 200	20.5 / 41			1 month after ①
③	C.P.N. / 400	15 / 60		15 / 60	2nd. season
Total		151	250	202	

Middle lands (early season)

①	A-20 / 800	6.25 / 50	31.25 / 250	17.75 / 142	At start
②	C.P.N. / 100	15 / 15		15 / 15	1 month after ①
③	C.P.N. / 100	15 / 15		15 / 15	1 month after ②
④	A.S. / 400	20.5 / 82			2nd. season
⑤	C.P.N. / 200	15 / 30		15 / 30	" "
Total		192	250	202	

Middle lands (Late season-after July 1st)

①	A-20 / 800	6.25 / 50	31.25 / 250	17.75 / 142	At start
②	A.S. / 400	20.5 / 82			2nd. season
③	C.P.N. / 400	15 / 60		15 / 60	" "
Total		192	250	202	

Middle lands (Short Ratoons)

①	A-20 / 400	6.25 / 25	31.25 / 125	17.75 / 71	At start
②	C.P.N. / 300	15 / 45		15 / 45	1 month after ①
③	A.S. / 200	20.5 / 41			1 month after ②
④	A.S. / 350	20.5 / 72			1½ months after ③
⑤	A.S. / 350	20.5 / 72			1½ months after ④
Total		255	125	116	

Middle lands (Middle season-after Apr. 1st)

①	A-20 / 800	6.25 / 50	31.25 / 250	17.75 / 142	At start
②	C.P.N. / 200	15 / 30		15 / 30	1 month after ①
③	A.S. / 400	20.5 / 82			2nd season
④	C.P.N. / 200	15 / 30		15 / 30	" "
Total		192	250	202	

Makai lands (Early season)

①	A-20 / 400	6.25 / 25	31.25 / 125	17.75 / 71	At start
②	C.P.N. / 300	15 / 45		15 / 45	1 month after ①
③	A.S. / 200	20.5 / 41			1 month after ②
④	A.S. / 350	20.5 / 72			2nd. season
⑤	A.S. / 350	20.5 / 72			" "
Total		225	125	116	

Makai land (Late season-after July 1st)

①	A-20 / 400	6.25 / 25	31.25 / 125	17.75 / 71	At start
②	C.P.N. / 300	15 / 45		15 / 45	1 month after ①
③	A.S. / 200	20.5 / 41			2nd. season
④	A.S. / 350	20.5 / 72			" "
⑤	A.S. / 350	20.5 / 72			" "
Total		225	125	116	

GROVE FARM CO.

Mauka - Plant - Unirrigated

①	R.R.P. / 500		36 / 180		With seed
②	PSSAX / 1500	.75 / 11	21 / 315	18.5 / 277.5	6 weeks after ①
③	A.S. / 500	20.5 / 102.5			2-3 months after ②
	Total	113.5	495	277.5	

Mauka - Long and Short Rat. - Unirrigated

①	PSSAX / 1250	.75 / 9.4	21 / 262.5	18.5 / 231¼	When field is cleaned up
②	A.S. / 500	20.5 / 102.5			1-2 months after ①
	Total	111.9	262.5	231¼	

Makai - Ratoons - Irrigated

①	PSSA / 1000	.75 / 7.5	21 / 210	18.5 / 185	At start
②	A.S. / 400	20.5 / 82			6 weeks after ①
③	A.S. / 400	20.5 / 82			3 months after ② or 2nd season
	Total	171.5	210	185	

Middle belt - Ratoons - Irrigated

①	PSSA / 1250	.75 / 9.4	21 / 262.5	18.5 / 231.3	At start
②	A.S. / 400	20.5 / 82			6 weeks after ①
③	A.S. / 300	20.5 / 61.5			3 months after ② or 2nd season
	Total	152.9	267.5	231.3	

Makai - Plant - Irrigated

①	R.R.P. / 400		36 / 180		With seed
②	PSSA / 1000	.75 / 7.5	21 / 210	18.5 / 185	6 weeks after ①
③	A.S. / 400	20.5 / 82			2-3 months after ②
④	A.S. / 400	82			3 months after ③ or 2nd season
	Total	171.5	390	185	

Middle belt - Plant - Irrigated

①	R.R.P. / 400		36 / 180		With seed
②	PSSA / 1500	.75 / 11	21 / 315	18.5 / 277.5	6 weeks after ①
③	A.S. / 300	20.5 / 61.5			2-3 months after ②
④	A.S. / 300	20.5 / 61.5			2nd season
	Total	134	495	277.5	

KOLOA SUGAR CO

Mauka lands - Unirrigated

①	A-16 / 250	11 / 27.5	40 / 100		Right after harvest
②	A-16 / 375	11 / 41¼	40 / 150		6-8 weeks after ①
③	X50A / 500	15.4 / 77		40 / 200	" " " ②
	Total	145¾	250	200	

Irrigated

①	A-16 / 375	11 / 41¼	40 / 150		Right after harvest
②	X50A / 437.5	15.4 / 67⅜		40 / 175	6-8 weeks after ①
③	A.S. / 500	20.5 / 102.5			6 weeks after ②
	Total	211⅛	150	175	

Mahaulepu Fields (Early cut) 1935

①	A-16 / 375	11 / 41¼	40 / 150		Right after harvest
②	X50A / 375	15.4 / 57¾		40 / 150	6 weeks after ①
③	A.S. / 350	20.5 / 71¾			" " ②
④	X50A / 250	15.4 / 38.5		40 / 100	4-6 wks. after ③
	Total	209¼	150	250	

Mauka lands - Unirrig. & Irrig. middle belt

①	A-20 / 400	6.25 / 25	31.25 / 125	17.75 / 71	Right after harvest
②	A-20 / 400	6.25 / 25	31.25 / 125	17.75 / 71	6 weeks after ①
③	A.S. / 200	20.5 / 41			4 " " ②
④	C.P.N. / 400	15 / 60		14 / 56	4-6 " " ③
	Total	151	250	198	

Mahaulepu Fields (Early cut) 1936

①	A-20 / 500	6.25 / 31¼	31.25 / 156¼	17.75 / 88¾	Right after harvest
②	C.P.N. / 300	15 / 45		14 / 42	6 weeks after ①
③	C.P.N. / 300	15 / 45		14 / 42	6 " " ②
④	C.P.N. / 300	15 / 45		14 / 42	4 " " ③
⑤	C.P.N. / 250	15 / 37.5		14 / 35	4 " " ④
	Total	203¾	156¼	249¾	

Irrigated (Early cut)

①	A-20 / 500	6.25 / 31¼	31.25 / 156¼	17.75 / 88¾	Right after harvest
②	A.S. / 200	20.5 / 41			6 weeks after ①
③	C.P.N. / 300	15 / 45		14 / 42	6 " " ②
④	A.S. / 200	20.5 / 41			4 " " ③
⑤	C.P.N. / 300	15 / 45		14 / 42	4 " " ④
	Total	203¾	156¼	172¾	

McBRYDE SUGAR CO.

Group A

①	A.P / 375	10.5 / 39	48 / 180		6 weeks of age
②	A.S. / 244	20.5 / 50			3 months of age
③	M.P. / 250			60 / 150	3 ″ ″
④	A.S. / 244	20.5 / 50			5-6 ″ ″
⑤	A.S. / 317	20.5 / 65			8-12 ″ ″
	Total	204	180	150	

Group B

①	A.P. / 375	10.5 / 39	48 / 180		Same as Group A
②	A.S. / 244	20.5 / 50			″ ″
③	M.P. / 250			60 / 150	″ ″
④	A.S. / 244	20.5 / 50			″ ″
⑤	A.S. / 244	20.5 / 50			″
⑥	A.S. / 171	20.5 / 35			″ ″
	Total	224	180	150	

Group C

①	A.P. / 375	10.5 / 39	48 / 180		6-8 weeks of age
②	A.S. / 244	20.5 / 50			Same as Group A
③	M.P. / 250			60 / 150	″ ″
④	A.S. / 244	20.5 / 50			″ ″
⑤	A.S. / 244	20.5 / 50			″ ″
⑥	A.S. / 268	20.5 / 55			″ ″
	Total	244	180	150	

Group D

①	A.P. / 375	10.5 / 39	48 / 180		6-8 weeks of age
②	A.S. / 244	20.5 / 50			Same as Group A
③	M.P. / 312			60 / 188	″ ″
④	A.S. / 244	20.5 / 50			″ ″
⑤	A.S. / 244	20.5 / 50			″ ″
⑥	A.S. / 171	20.5 / 35			″ ″
	Total	224	180	188	

Group E

①	R.R.P. / 500		36 / 180		With seed
②	A.P. / 375	10.5 / 39	48 / 180		6-8 weeks of age
③	A.S. / 350	20.5 / 72			3 months of age
④	M.P. / 250			60 / 150	3 ″ ″
⑤	A.S. / 350	20.5 / 72			6 ″ ″
	Total	183	360	150	

Group F

①	R.R.P. / 500		36 / 180		With seed
②	A.P. / 375	10.5 / 39	48 / 180		6-8 weeks of age
③	A.S. / 244	20.5 / 50			3 months of age
④	M.P. / 250			60 / 150	3 ″ ″
⑤	A.S. / 244	20.5 / 50			6 ″ ″
⑥	A.S. / 317	20.5 / 65			8-10 ″ ″
	Total	204	360	150	

Group G

①	R.R.P. / 500		36 / 180		With seed
②	A.P. / 375	10.5 / 39	48 / 180		Same as Group F
③	A.S / 244	20.5 / 50			″ ″
④	M.P. / 250			60 / 150	″ ″
⑤&⑥	A.S / 244	20.5 / 50			″ ″
⑦	A.S / 171	20.5 / 35			″ ″
	Total	224	360	150	

Group H

①	R.R.P. / 500		36 / 180		With seed
②	A.P. / 375	10.5 / 39	48 / 180		6-8 weeks of age
③	A.S. / 244	20.5 / 50			Same as Group F
④	M.P. / 312			60 / 188	″ ″
⑤&⑥	A.S. / 244	20.5 / 50			″# ″
⑦	A.S. / 171	20.5 / 35			″* ″
	Total	224	360	188	

McBRYDE SUGAR CO.

Group I					
①	A.P. / 375	10.5 / 39	48 / 180		6-8 weeks of age
②	A S / 350	20.5 / 72			3 months of age
③	M P / 250			60 / 150	3 " "
④	A.S. / 350	20.5 / 72			6 " "
	Total	183	180	150	

LEGEND

A - For fields low in P_2O_5 and medium low in K_2O, and not requiring as heavy N as B and C groups.

B - For fields low in P_2O_5 and medium low in K_2O, and requiring more N than A and less than C group.

C - For fields low in P_2O_5 and medium low in K_2O, and requiring maximum N.

D - For fields known to be low in K_2O and P_2O_5.

E - Plant fields requiring low N, on account of variety, or of receiving mudpress cake or manure. These fields low in P_2O_5 and medium low in K_2O, receive Raw Rock Phosphate as supplemental dose.

F - This group for plant fields which had less mudpress cake, if any, and requiring more N than E group.

G - Same as F group except require more N, plant fields.

H - Plant fields low in K_2O and P_2O_5.

I - Fields low in P_2O_5, medium low in K_2O, and not requiring much N, due to variety or growing time as S. R. etc.

HAWAIIAN SUGAR CO

For long ratoons when molasses ash is used

①	H.S.-3 / 343.75	13.25 / 45.55	33.4 / 114.8		Soon after start
②	Mol.Ash / 350			115.71	In first water
③	A.S. / 682.5	20.6 / 140.6			Applied in 3 or 4 doses
④	M.P. / 133			60 / 79.8	With last appl. of A.S.
⑤	N.S. / 400	16 / 64			In 2 doses not later than June
	Total	250	114.8	195.5	

For long ratoons where no molasses ash is used

①	H.S.-2 / 625	7.25 / 45.31	17.75 / 110.95	19.25 / 120.3	Soon after start
②	A.S. / 682.5	20.5 / 140.6			Applied in 3 or 4 doses
③	M.P. / 133			60 / 79.8	With last appl. of A.S.
④	N.S. / 400	16 / 64			In 2 doses not later than June
	Total	250	111	200	

Short ratoons

①	H.S-2 / 625	7.25 / 45.3	17.75 / 110.94	19.25 / 120.31	Soon after start
②	A.S. / 400	20.6 / 82.4			In 2 doses just after High Grade application
③	N.S. / 300	16 / 48			About middle of May not later than June
	Total	175.7	110.94	120.31	

Long ratoons - above Mill Ditch

①	H.S.-4 / 625	8 / 50	32 / 200	16 / 100	Soon after start
②	A.S. / 450	20.5 / 92.7			In two applications-following High Grade
③	C.P.N. / 715	15 / 107¼		14 / 100.1	Applied 3 or 4 doses not later than June
	Total	249.95	200	200.1	

Long ratoons - below Mill Ditch

①	H.S.-3 / 343.7	13.25 / 45.5	33.4 / 114.8		Soon after start
②	N.S. / 937.5	16 / 150			In 5 or 6 applications, 3 in 2nd season
	Total	195.5	114.8		

Short ratoons 1936 Crop

①	H.S.-3 / 343.7	13.25 / 45.5	33.40 / 114.8		Soon after start
②	C.P.N. / 857	15 / 128.5		14 / 120	In 4 applications not later than June
	Total	174.1	114.8	120	

WAIMEA SUGAR MILL CO.

Short ratoons

①	A-17 / 250	9.5 / 23¾	41.5 / 103¾		Before first irrigation
②	N.S. / 250	15.5 / 38¾			1 month after ①
③	X50-A / 250	15.4 / 38.5		40 / 100	6 weeks after ②
④	N.S. / 375	15.5 / 58.1			6 " " ③
⑤	X50-A / 375	15.4 / 57¾		40 / 150	6 " " ④
	Total	216.85	103¾	250	

Long ratoons

①	A-17 / 250	9.5 / 23¾	41.5 / 103¾		After harvest
②	A.S. / 200	20.5 / 41			1 month after ①
③	X50-A / 250	15.4 / 38.5		40 / 100	6 weeks after ②
④	N.S. / 250	15.5 / 38¾			Feb. or March
⑤	X50-A / 250	15.4 / 38.5		40 / 100	6 weeks after ④
	Total	180.5	103¾	200	

KEKAHA SUGAR CO.

Makai - Short ratoons

1	A-17 / 250	9.5 / 24	41.5 / 104		Immediately after harvest
2	X56 / 375	13.5 / 50		17 / 64	4-6 weeks after (1)
3	X56 / 375	13.5 / 50		17 / 64	6 " " (2)
4	X56 / 375	13.5 / 50		17 / 64	6 " " (3)
5	X56 / 375	13.5 / 50		17 / 64	6 " " (4)
	Total	224	104	256	

Mauka - Short ratoons

1	A-17 / 625	9.5 / 59	41.5 / 259		Immediately after harvest
2	X56 / 375	13.5 / 50		17 / 64	Approx. 6 weeks after (1)
3	X56 / 375	13.5 / 50		17 / 64	6 weeks after (2)
4	X56 / 375	13.5 / 50		17 / 64	6 " " (3)
5	A S / 200	20.5 / 41			6 " " (4)
	Total	250	259	192	

Makai - Long ratoons

1	A-17 / 250	9.5 / 24	41.5 / 104		Immediately after harvest
2	X56 / 375	13.5 / 50		17 / 64	6 weeks after (1)
3	X56 / 375	13.5 / 50		17 / 64	6 " " (2)
4	N.S. / 250	16 / 40			Second Season March
5	X50-A / 375	15.4 / 58		40 / 150	Second season 6 weeks after (4)
	Total	222	104	278	

Mauka - Long ratoons

1	A-17 / 625	9.5 / 59	41.5 / 250		Immediately after harvest
2	X56 / 375	13.5 / 50		17 / 64	4-6 weeks after (1)
3	X56 / 375	13.5 / 50		17 / 64	6 " " (2)
4	N.S. / 250	16 / 40			Second Season March
5	X50-A / 250	15.4 / 38		40 / 100	Second season 6 weeks after (4)
	Total	237	259	228	

Short ratoons

1	A-17 / 250	9.5 / 24	41.5 / 104		Immediately after harvest
2	A.S. / 250	20.5 / 50			4-6 weeks after
3	X50-A / 250	15.4 / 38		40 / 100	6 " "
4	A.S. / 300	20.5 / 60			6 " "
5	X50-A / 250	15.4 / 38		40 / 100	6 " "
	Total	210	104	200	

PIONEER MILL CO.

PLANT AND LONG RATOONS

General

1	A-17 / 500	9.5 / 47.5	41.5 / 207.5		April to August
2	N.P. / 250	13.2 / 33		44.9 / 112.2	June to September
3	A.S. / 350	20.8 / 72.8			August to November
4	A.S. / 250	20.8 / 52			January to February
5	A.S. / 250	20.8 / 52			February to March
Total	2573	207.5	112.2		

Middle and Mauka fields not receiving mol.

1	A-19 / 750	6.7 / 50.2	29.25 / 219.4	16 / 120	April to August
2	A.S. / 250	20.8 / 52			June to October
3	A.S. / 250	20.8 / 52			August to November
4	A.S. / 250	20.8 / 52			January to February
5	A.S. / 250	20.8 / 52			February to March
Total	258.2	219.4	120		

Makai, receiving molasses and/or pump water

1	A-17 / 500	9.5 / 47.5	41.5 / 207.5		April to August
2	A.S. / 250	20.8 / 52			June to October
3	A.S. / 250	20.8 / 52			August to November
4	A.S. / 250	20.8 / 52			January to February
5	A.S. / 250	20.5 / 52			February to March
Total	255.5	207.5			

Makai, receiving molasses and/or pump water

1	A.P.-A / 500	11.1 / 55.5	49.2 / 246		April to August
2	A.S. / 250	20.8 / 52			June to October
3	A.S. / 250	20.8 / 52			August to November
4	A.S. / 250	20.8 / 52			January to February
5	A.S. / 250	20.8 / 52			February to March
Total	263.5	246			

SHORT RATOONS

Middle and Mauka fields not receiving mol.

1	A-19 / 750	6.7 / 50.2	29.25 / 219.4	16 / 120	December to March
2	A.S. / 250	20.8 / 52			February to May
3	A.S. / 250	20.8 / 52			April to July
4	A.S. / 250	20.8 / 52			July to September
5	A.S. / 250	20.8 / 52			July to October
Total	258.2	219.4	120		

Fields below Pump Ditches &/or fields receiving mol.

1	A-17 / 500	9.5 / 47.5	41.5 / 207.5		December to March
2	A.S. / 250	20.8 / 52			February to May
3	A.S. / 250	20.8 / 52			April to July
4	A.S. / 250	20.8 / 52			June to September
5	A.S. / 250	20.8 / 52			July to October
Total	255.5	207.5			

Middle belt, not receiving molasses

1	A-19 / 750	6.7 / 50.2	29.25 / 219.4	16 / 120	January to March
2	A.S. / 250	20.8 / 52			February to May
3	A.S. / 250	20.8 / 52			April to July
4	A.S. / 250	20.8 / 52			June to September
5	A.S. / 250	20.8 / 52			July to October
Total	258.2	219.4	120		

Makai, receiving molasses and/or pump water

1	A.P.-A / 500	11.1 / 55.5	49.2 / 246		January to March
2	A.S. / 250	20.8 / 52			February to May
3	A.S. / 250	20.8 / 52			April to July
4	A.S. / 250	20.8 / 52			June to September
5	A.S. / 250	20.8 / 52			July to October
Total	263.5	246			

PIONEER MILL CO.

Plant and Long Ratoons
Middle belt fields not receiving molasses

(1)	A-19 / 750	67 / 50.2	29.25 / 219.4	16 / 120	April to August
(2)	A.S. / 250	20.8 / 52			June to October
(3)	A.S. / 250	20.8 / 52			August to November
(4)	A.S. / 250	20.8 / 52			January to February
(5)	A.S. / 250	20.8 / 52			February to March
Total		258.2	219.4	120	

Short Ratoons
Extreme Mauka conditions and "G" fields

(1)	A-19 / 750	67 / 50.2	29.25 / 219.4	16 / 120	January to March
(2)	A.S. / 250	20.8 / 52			February to May
(3)	X-35 / 250	22 / 55		29 / 72.5	April to July
(4)	A.S. / 250	20.8 / 52			June to September
(5)	A.S. / 250	20.8 / 52			July to October
Total		261.2	219.4	192.5	

Plant and Long Ratoons
All extreme Mauka and "G" fields

(1)	A-19 / 750	67 / 50.2	29.25 / 219.4	16 / 120	April to August
(2)	A.S. / 250	20.8 / 52			June to October
(3)	C.P.N. / 375	14.4 / 54		18.79 / 70.46	August to November
(4)	A.S. / 250	20.8 / 52			January to February
(5)	A.S. / 250	20.8 / 52			February to March
Total		260.2	219.4	190.46	

MAUI AGRICULTURAL CO.

Early started fields up to and including February

(1)	A.P. / 200	11 / 22	48 / 96		As soon as possible after harvest. With seed
(2)	A.S. / 200	20.5 / 41.5			2 months of age
(3)	A.S. / 200	20.5 / 41.5			3 " "
(4)	A.S. / 200	20.5 / 41.5			5 " "
(5)	A.S. / 200	20.5 / 41.5			7 " "
(6)	A.S. / 250	20.5 / 52			February of the 2nd year
Total		240	96		

Intermediate started fields - March to May inclusive

(1)	A.P. / 200	11 / 22	48 / 96		As soon as possible on ratoons. With seed
(2)	A.S. / 200	20.5 / 41.5			2 months of age
(3)	A.S. / 200	20.5 / 41.5			3 " "
(4)	A.S. / 200	20.5 / 41.5			4 " "
(5)	A.S. / 200	20.5 / 41.5			February
(6)	A.S. / 250	20.5 / 52			March or April
Total		240	96		

Late started fields - June, July and August

(1)	A.P. / 200	11 / 22	48 / 96		With seed Ratoons-2 wks. of age
(2)	A.S. / 250	20.5 / 52			Plant - 1 month of age
(3)	A.S. / 300	20.5 / 62			Age 2 months, but before Sept 30.
(4)	A.S. / 250	20.5 / 52			February - 2nd year
(5)	A.S. / 250	20.5 / 52			April - Second year
Total		240	96		

WAILUKU SUGAR CO.

Early started - First of December to end of February. POJ 2878 - 13 to 14 months.

①	A.S. 200	20.8 41			Rat. 3 wks. after harvest. Plant - 5-6 wks. after pltg.
	M.P. 250			60 150	If the field requires it
②	A.S. 200	20.8 41			1 month after ①
③	A.S. 250	20.8 52			2 months after ②
④	A.S. 200	20.8 41			2 " " ③
	Total	175		150	

Early started - First of December to the end of February. H 109 - 18 to 20 months.

①	A.S. 200	20.8 41			Ratoons 3-4 weeks after harvest
	M.P. 250			60 150	If necessary
②	A.S. 200	20.8 41			1 month after ①
③	A.S. 300	20.8 62			3 months after ②
④	A.S. 300	20.8 62			2-3 " " ③
	Total	206		150	

Intermediate started - March to May inclusive. POJ 2878 - 13 to 14 months.

①	A.S. 200	20.8 41			Rat. 3-4 wks. after harvest. Plant 5-6 wks. after Pltg.
	M.P. 250			60 150	If necessary
②	A.S. 200	20.8 41			1 month after ①
③	A.S. 250	20.8 52			2 months after ②
④	A.S. 200	20.8 41			2 " " ③
	Total	175		150	

Intermediate started - April to July inclusive. H 109 - 18 to 20 months.

①	A.S. 200	20.8 41			Ratoons 3-4 weeks after harvest.
	M.P. 250			60 150	If field requires
②	A.S. 250	20.8 52			1 month after ①
③	A.S. 250	20.8 52			2-3 months after ②
④	A.S. 300	20.8 62			February
	Total	206		150	

Very late - September to November inclusive. POJ 2878 - 13 to 14 months.

①	A.S. 200	20.8 41			Rat. 3 wks. after harvest Plant 4-5 wks. after pltg.
	M.P. 250			60 150	If necessary
②	A.S. 200	20.8 41			1 month after ①
③	A.S. 250	20.8 52			February to March
④	A.S. 200	20.8 41			March to April
	Total	175		150	

Late crop started August to November inclusive. H 109 - 18 to 20 months.

①	A.S. 200	20.8 41			Ratoons 2-3 weeks after harvest.
	M.P. 250			60 150	If necessary
②	A.S. 200	20.8 41			Not more than 1 month after ①
③	A.S. 300	20.8 62			February to March
④	A.S. 300	20.8 62			April to May
	Total	206		150	

Late crop - June to August inclusive. POJ 2878 - 13 to 14 months.

①	A.S. 200	20.8 41			Rat. 3 wks. after harvest Plant 4-5 wks. after pltg.
	M.P. 250			60 150	If field requires
②	A.S. 250	20.8 52			1 month after ①
③	A.S. 200	20.8 41			January to February
④	A.S. 200	20.8 41			February to March
	Total	175		150	

Note:- For fields requiring P_2O_5 - substitute 375# applic of Ammophos (11% N - 49% P_2O_5) for first A.S. applic (184# P_2O_5)

H.C.& S. CO.

Long ratoons. Early started - Mauka fields or those receiving mountain water only

1	G-2 / 630	4 / 25	28 / 176.5	16 / 101	After first water
2	A.S. / 200	20.5 / 41			On before end of June
3	A.S. / 200	20.5 / 41			
4	A.S. / 200	20.5 / 41			On by end of Sept.
5	A.S. / 200	20.5 / 41			January
6	N.S. / 350	15.5 / 54			March
Total		243	176.5	101	

Long crop. Early started All fields receiving pump water

1	A.P. / 350	10.7 / 37.5	49.5 / 173		Plant - as soon as it is up Rat. - as soon as possible Applied after irrigation
2	A.S. / 200	20.5 / 41			Before end of June
3	A.S. / 200	20.5 / 41			
4	A.S. / 200	20.5 / 41			On by end of Sept
5	A.S. / 200	20.5 / 41			January
6	N.S. / 350	15.5 / 54			March
Total		255	173		

Short ratoons. Makai fields or those receiving mountain water only

1	G-2 / 630	4 / 25	28 / 176.5	16 / 101	After first water-covered
2	A.S. / 200	20.5 / 41			
3	A.S. / 200	20.5 / 41			
4	A.S. / 200	20.5 / 41			
5	A.S. / 200	20.5 / 41			
6	A.S. / 200	20.5 / 41			All on by end of Sept.
Total		230	176.5	101	

Short ratoons. All fields receiving pump water

1	A.P. / 350	10.7 / 37.5	49.5 / 173		As soon as possible after first irrigation when ground is wet
2	A.S. / 200	20.5 / 41			
3	A.S. / 200	20.5 / 41			
4	A.S / 200	20.5 / 41			
5	A.S. / 200	20.5 / 41			
6	A.S / 200	20.5 / 41			All on by end of Sept.
Total		242	173		

Long crop. Late started. All fields

1	A.P. / 350	10.7 / 37	49.8 / 173		Plant-as soon as it is up Rat.-as soon as possible Applied after irrigation
2	A.S. / 200	20.5 / 41			
3	A.S. / 200	20.5 / 41			On by end of September
4	A.S. / 200	20.5 / 41			January
5	N.S. / 350	15.5 / 54			March
Total		214	173		

WAIMANALO SUGAR CO.

Fields high in Phosphate

1	C.P.N. / 625	15 / 93.7		13.5 / 84.4	Immediately after harvest
2	C.P.N. / 625	15 / 93.7		13.5 / 84.4	Within 3 months
	Total	187.4		168.8	

Plant fields low in Phosphate & Potash

1	R.R.P. / 500		36 / 180		With seed
2	C.P.N. / 500	15 / 75		13.5 / 67.5	1 month after 1
3	C.P.N / 700	15 / 105		13.5 / 94.5	" " 2
	Total	180	180	162	

Ratoon fields low in Phosphate & Potash

1	Di.A.P. / 250	20.4 / 50	45.7 / 112.5		Immediately after harvest
	C.P.N. / 325	15 / 56.3		13.5 / 50.6	
2	C.P.N. / 500	15 / 75		13.5 / 67.5	3 months after 1
	Total	181.3	112.5	118.1	

Fields high in Phosphate and Potash

1	N.S. / 625	15.5 / 97			Immediately after harvest
2	N.S. / 625	15.5 / 97			3 months after 1
	Total	194			

KAHUKU PLANTATION CO.

Short ratoons

1	A.P. / 450	16.5 / 74	20 / 90		Right after harvest
	M.P. / 150			60 / 90	" "
2	A.S. / 350	20.5 / 72			2 months after 1
	Total	146	90	90	

Long ratoons

1	A.P. / 500	16.5 / 82.5	20 / 100		Right after harvest
	M.P. / 175			60 / 105	" "
2	A.S. / 150	20.5 / 31			2 months after 1
3	A.S. / 300	20.5 / 61.5			Spring of the Second year
	Total	175	100	105	

WAIANAE CO.

Long ratoons

1	A-21 / 500	5 / 25	20 / 100	20 / 100	2 wks. after harvest
2	A.S. / 250	20.5 / 51.5			2 months after 1
3	A.S. / 250	20.5 / 51.5			" " 2
4	C.P.N. / 200	14.6 / 29		14 / 28	" " 3
5	C.P.N. / 500	14.6 / 73		14 / 70	2nd. Season
	Total	230	100	198	

Short ratoons

1	A-15 / 500	9 / 45	20 / 100	20 / 100	Right after harvest
2	A.S. / 250	20.5 / 51.5			2 months after 1
3	A.S. / 250	20.5 / 51.5			" " 2
4	Urea/MP / 375	62.5		108	June or July of the first year
	Total	230.5	100	208	

WAIALUA AGRICULTURAL CO.

Long ratoons - Started in Jan., Feb. or March

①	A.S. 250	20.5 51			1 or 2 months after harvest
②	A.P. 300	10.5 32	49 147		Soon after ①
③	M.P. 100			60 60	" " ②
④	A.S. 400	20.5 82			1½ months after ③
⑤	A.S. 200	20.5 41			February of 2nd year
⑥	A.S. 200	20.5 41			March of 2nd year
	Total	247	147	60	

Long ratoons - Started in April or May

①	A.S. 500	20.5 103			As soon as possible
②	A.P. 400	10.5 42	49 196		Soon after ①
③	M.P. 125			60 75	" " ②
④	A.S. 250	20.5 51			February of 2nd year
⑤	A.S. 250	20.5 51			April of 2nd year
	Total	247	196	75	

Long ratoons - Started in June or July

①	A.S. 400	20.5 82			As soon as possible
②	A.P. 400	10.5 42	49 196		" "
③	M.P. 125			60 75	Soon after ②
④	A.S. 300	20.5 62			February of 2nd year
⑤	A.S. 300	20.5 62			April or May of 2nd year
	Total	248	196	75	

Long ratoons - Started in August

①	A.S. 350	20.5 72			As soon as possible
②	A.P. 300	10.5 32	49 147		" "
③	M.P. 125			60 75	Soon after ②
④	A.S. 350	20.5 72			February of 2nd year
⑤	A.S. 350	20.5 72			May of 2nd year
	Total	248	147	75	

Plant

①	Super 500		20.5 103		With seed
②	A.S. 300	20.5 62			2 months after planting
③	M.P. 125			60 75	Soon after ②
④	A.S. 400	20.5 82			1 - 2 months after ②
⑤	A.S. 250	20.5 51			February of 2nd year
⑥	A.S. 250	20.5 51			March of 2nd year
	Total	246	103	75	

EWA PLANTATION CO.

I — For Lands that get no Potash (12% of the plantation)

	Long Ratoons, Started April, May, June and July	N		K₂O	Notes	Long Plant: Started any time; Long Ratoons: Started after Aug. 15	N		K₂O	Notes
①	A.S. / 275	20.5 / 56			6 wks. after harvest	A.S. / 275	20.5 / 56			6 wks. after harvest. 12 wks. or after planting.
②	A.S. / 500	20.5 / 102.5			7 wks. after ①	A.S. / 500	20.5 / 102.5			2nd. season
③	N.L.* / 500	15.5 / 77.5			8 wks. after ② or 2nd. season	N.L.* / 500	15.5 / 77.5			" "
	Total	236				Total	236			

II — For Lands that get 75 to 125 lbs. Potash per acre (20% of the plantation)

	Long Ratoons	N		K₂O	Notes	Long Plant / Long Ratoons	N		K₂O	Notes
①	A.S. / 300	20.5 / 61.5			6 wks. after harvest	A.S. / 300	20.5 / 61.5			Same notes as above
②	A.S. / 500	20.5 / 102.5			8 wks. after ①	A.S. / 500	20.5 / 102.5			"
③	C.P.N. / 525	14.5 / 76		14 / 73.5	8 wks. after or 2nd. season	C.P.N. / 525	14.5 / 76		14 / 73.5	"
	Total	240		73.5		Total	240		73.5	

(For insurance only) Low in K₂O based on juice analysis

	Long Ratoons	N		K₂O	Notes	Long Plant / Long Ratoons	N		K₂O	Notes
①	A.S. / 275	20.5 / 56			Same notes as above	A.S. / 275	20.5 / 56			Same notes as above
②	C.P.N. / 700	14.5 / 101.5		14 / 98	"	C.P.N. / 700	14.5 / 101.5		14 / 98	"
③	N.L. / 500	15.5 / 77.5			"	N.L. / 500	15.5 / 77.5			"
	Total	235		98		Total	235		98	

III — For Lands that get 200 to 250 lbs. Potash per acre (58% of the plantation)

	Long Ratoons	N		K₂O	Notes	Long Plant / Long Ratoons	N		K₂O	Notes
①	A.S. / 275	20.5 / 56			6 wks after harvest	A.S. / 275	20.5 / 56			Same notes as above
②	A.S. / 500	20.5 / 101.5			8 wks. after ①	A.S. / 500	20.5 / 101.5			"
③	M.P. / 400			60 / 240	In water at 5 months	M.P. / 400			60 / 240	"
④	N.L. / 500	15.5 / 77.5			8 wks. after ③ or 2nd. season	N.L. / 500	15.5 / 77.5			"
	Total	235		240		Total	235		240	

IV — For Lands that get 300 to 400 lbs. Potash per acre (10% of the plantation)

	Long ratoons and long plant	N		K₂O
①	A.S. / 275	20.5 / 56		
②	A.S. / 500	20.5 / 101.5		
③	M.P. / 625			60 / 375
④	N.L. / 500	15.5 / 77.5		
	Total	235		375

	Long ratoons	N		K₂O
①	A.S. / 275	20.5 / 56		
②	A.S. / 500	20.5 / 101.5		
③	M.P. / 625			60 / 375
④	A.S. / 375	20.5 / 77.5		
	Total	235		375

* N.L. used in place of N.S. on all wet fields. A.S. used in place of N.L. on all coral fields. This applies throughout.

If 8 weeks later comes after the middle of October, application is postponed to Spring of 2nd. year

Note:- All fertilizer applied by hand, size and condition of cane permitting. 2nd.-season fertilizer applied in water. Owing to lower efficiency of water vs. hand application, the total application of N is increased by 25 pounds per acre when water application employed.

Note:- A.P. (10.7% N - 48% P_2O_5) used on fields low in P_2O_5 in place of A.S. in ① application.

EWA PLANTATION CO.

						SHORT RATOONS			SHORT PLANT
						Started Jan.	Started Feb.	Started Mar.	Started Jan. & Feb.
I For Lands that get no Potash (12% of the plantation)	(1)	A.S.* 275	20.5 / 56			10 wks. after harvest	8 wks after harvest	7 wks. after harvest	12 wks. after planting
	(2)	N.L.* 800	15.5 / 124			7 wks. after (1)	7 wks. after (1)	7 wks. after (1)	7 wks after (1)
	Total		180						
II For Lands that get 75 to 125 lbs. Potash per acre (20% of the plantation) (For insurance only)	(1)	A.S. 275	20.5 / 56			”	”	”	”
	(2)	C.P.N. 900	14.5 / 130.5		14 / 126				
	Total		186.5		126				
III For Lands that get 200 to 250 lbs. Potash per acre (58% of the plantation)	(1)	A.S.* 275	20.5 / 56						
	(2)	A.S. 600	20.5 / 123			”	”	”	”
	(3)	M.P. 400			60 / 240	In water at 5 months			
	Total		179		240				
IV For Lands that get 300 to 400 lbs. Potash per acre (10% of the plantation)	Good Soils and Wet Soils,								
	(1)	N.L. 350	15.5 / 54						
	(2)	N.L. 800	15.5 / 124			”	”	”	”
	(3)	M.P. 675			60 / 405				
	Total		178		405				
	Coral Lands								
	(1)	A.S. 275	20.5 / 56						
	(2)	A.S. 600	20.5 / 123			”	”	”	”
	(3)	M.P. 675			60 / 405				
	Total		179		405				

OAHU SUGAR CO.

Early start - December, January & February

1	A-14 / 400	7 / 28	20.5 / 82	17 / 68	As soon as possible
2	A-14 / 700	7 / 49	20.5 / 143.5	17 / 119	8-12 weeks after 1
3	A.S. / 500	20.5 / 102.5			May or July
4	N.S. / 625	15.5 / 97			2nd. Season
Total		276.5	225.5	187	

Late start (After May 15)

1	A-14 / 1100	7 / 77	20.5 / 225.5	17 / 187	As soon as possible
2	A.S. / 350	20.5 / 71.8			July
3	N.S. / 500	15.5 / 77.5			2nd. season February or March
4	N.S / 375	15.5 / 58			2nd. season (April)
Total		284.3	225.5	187	

Intermediate (March, April and May)

1	A-14 / 400	7 / 28	20.5 / 82	17 / 68	As soon as possible
2	A-14 / 700	7 / 49	20.5 / 143.5	17 / 119	4-8 weeks after 1
3	A.S. / 350	20.5 / 71.8			June or July
4	N.S. / 500	15.5 / 77.5			2nd Season
5	N.S. / 375	15.5 / 58			" "
Total		284.3	225.5	187	

Plant cane

1	A-14 / 500	7 / 35	20.5 / 102.5	17 / 85	With seed
2	A-14 / 600	7 / 42	20.5 / 123	17 / 102	8-12 weeks after 1
3	A.S. / 300	20.5 / 61			May or June
4	N.S. / 500	15.5 / 77.5			2nd. season
5	N.S. / 375	15.5 / 58			" "
Total		273.5	225.5	187	

HONOLULU PLANTATION CO.

For low P_2O_5 and K_2O requirements
For H109 cane under 18 months cropping

1	A / 406	10.5 / 43	20.5 / 83	12.8 / 52	With Seed Ratoons with subsoiling
2	A.S. / 300	20.5 / 61.5			Following irrigation after subsoiling
3	A.S. / 300	20.5 / 61.5			Following 2nd irrigation after subsoiling
4	A.S. / 400	20.5 / 82			1 year after harvest
Total		248	83	52	

For low P_2O_5 and K_2O requirements
For POJ2878 under 12 months cropping

1	A / 406	10.5 / 43	20.5 / 83	18.8 / 76	With Seed Ratoons with subsoiling
2	A.S. / 200	20.5 / 41			Following irrigation after subsoiling
3	A.S / 200	20.5 / 41			Following 2nd irrigation after subsoiling
4	A.S. / 200	20.5 / 41			1 month after 3
Total		166	83	76	

Low P_2O_5 and medium K_2O requirements
For H109 cane under 18 months cropping

1	B / 531	8 / 42.5	19.4 / 103	24.3 / 129	Same notes as above
2	A.S. / 300	20.5 / 61.5			" "
3	A.S. / 300	20.5 / 61.5			" "
4	A.S. / 400	20.5 / 82			" "
Total		247.5	103	129	

Low P_2O_5 and medium K_2O requirements.
For POJ 2878 under 12 months cropping

1	B / 531	8 / 42.5	19.4 / 103	24.3 / 129	Same notes as above
2	A.S. / 200	20.5 / 41			" "
3	A.S. / 200	20.5 / 41			" "
4	A.S. / 200	20.5 / 41			" "
Total		165.5	103	129	

HONOLULU PLANTATION CO.

For low P_2O_5 and K_2O requirements
For H 109 cane under 18 months cropping

1	C / 625	6.7 / 42	32 / 200	20 / 125	With Seed Ratoons with subsoiling
2	A.S. / 300	20.5 / 61.5			Following irrigation after subsoiling
3	A.S. / 300	20.5 / 61.5			Following 2^{nd} irrigation after subsoiling
4	A.S. / 400	20.5 / 82			1 year before harvest
Total		247	200	125	

For low P_2O_5 and K_2O requirements
For POJ 2878 under 12 months cropping

1	C / 625	6.7 / 42	32 / 200	20 / 125	With seed Ratoons with subsoiling
2	A.S. / 200	20.5 / 41.5			Following irrigation after subsoiling
3	A.S. / 200	20.5 / 41.5			Following 2^{nd} irrigation after subsoiling
4	A.S. / 200	20.5 / 41.5			1 month after 3
Total		166.5	200	125	

For medium P_2O_5 and high K_2O requirements
For H 109 cane under 18 months cropping

1	D / 750	5.6 / 42	26.7 / 200	26.7 / 200	Same notes as above
2	A.S. / 300	20.5 / 61.5			" "
3	A.S. / 300	20.5 / 61.5			" "
4	A.S. / 400	20.5 / 82			" "
Total		247	200	200	

For medium P_2O_5 and high K_2O requirements
For POJ 2878 under 12 months cropping

1	D / 750	5.6 / 42	26.7 / 200	26.7 / 200	Same notes as above
2	A.S. / 200	20.5 / 41			" "
3	A.S. / 200	20.5 / 41			" "
4	A.S. / 200	20.5 / 41			" "
Total		165	200	200	

For high P_2O_5 and high K_2O requirements
For H 109 cane under 18 months cropping

1	E / 1000	4.1 / 41	30 / 300	20 / 200	Same notes as above
2	A.S. / 300	20.5 / 61.5			" "
3	A.S. / 300	20.5 / 61.5			" "
4	A.S. / 400	20.5 / 82			" "
Total		246	300	200	

For high P_2O_5 and high K_2O requirements
For POJ 2878 under 12 months cropping

1	E / 1000	4.1 / 41	30 / 300	20 / 200	Same notes as above
2	A.S. / 200	20.5 / 41			" "
3	A.S. / 200	20.5 / 41			" "
4	A.S. / 200	20.5 / 41			" "
Total		164	300	200	

For high P_2O_5 and medium K_2O requirements
For H 109 cane under 18 months cropping

1	F / 875	4.8 / 42	34.4 / 301	14.3 / 125	Same notes as above
2	A.S. / 300	20.5 / 61.5			" "
3	A.S. / 300	20.5 / 61.5			" "
4	A.S. / 400	20.5 / 82			" "
Total		247	301	125	

For high P_2O_5 and medium K_2O requirements
For POJ 2878 under 12 months cropping

1	F / 875	4.8 / 42	34.4 / 301	14.3 / 125	Same notes as above
2	A.S. / 200	20.5 / 41			" "
3	A.S. / 200	20.5 / 41			" "
4	A.S. / 200	20.5 / 41			" "
Total		165	301	125	

HONOLULU PLANTATION CO.

For poorly drained fields - low in P_2O_5 and low in K_2O requirements.
For H 109 cane under 18 months cropping

①	G / 595	7.1 / 42	17 / 101	8.6 / 51	With seed Ratoon with subsoiling
②	N.L. / 400	15.5 / 62			Following irrigation after subsoiling
③	N.L. / 400	15.5 / 62			Following 2nd irrigation after subsoiling
④	N.L. / 550	15.5 / 85			1 year before harvest
Total		251	101	51	

For poorly drained fields - low in P_2O_5 and low in K_2O requirements
For POJ 2878 under 12 months cropping

①	G / 250	7.1 / 18	17 / 42.5	8.6 / 21.5	With seed Ratoon with subsoiling
②	N.L. / 250	15.5 / 39			Following irrigation after subsoiling
③	N.L. / 250	15.5 / 39			Following 2nd irrigation after subsoiling
④	N.L. / 250	15.5 / 39			1 month after ③
Total		135	42.5	21.5	

For poorly drained fields - low in P_2O_5 and low in K_2O requirements
For H 109 cane under 18 months cropping

①	H / 844	4.9 / 41	12 / 101	23.8 / 201	Same notes as above
②	N.L. / 400	15.5 / 62			" "
③	N.L. / 400	15.5 / 62			" "
④	N.L. / 550	15.5 / 85			" "
Total		250	101	201	

For poorly drained fields - low in P_2O_5 and low in K_2O requirements
For POJ 2878 under 12 months cropping

①	H / 844	4.9 / 41	12 / 101	23.8 / 201	Same notes as above
②	N.L. / 400	15.5 / 62			" "
③	N.L. / 400	15.5 / 62			" "
④	N.L. / 550	15.5 / 85			" "
Total		250	101	201	

FERTILIZER FORMULA CHART

Plantation	Formula	Block No.
Grove Farm Co., Ltd.	PS5A	25
Hakalau Plantation Co.	B-25	13
Hamakua Mill Company	Hamakua M. F.	15
Hawaiian Agricultural Company	B-21	12
Hawaiian Commercial & Sugar Company	G-2	14
Hawaiian Sugar Company	H. S. 2	16
	H. S. 3	17
	H. S. 4	18
Hilo Sugar Company	B-19	11
Honokaa Sugar Company	Honokaa A	19
	Honokaa B	20
	Honokaa C	21
	Honokaa D	22
Honomu Sugar Company	B-17	10
Kekaha Sugar Company, Ltd.	A-17	6
	X50A	30
	X56	31
Kilauea Sugar Plantation Company	K-8	23
Koloa Sugar Company	A-16	5
	A-20	8
	X50A	30
Laupahoehoe Sugar Company	Laupahoehoe	24
Lihue Plantation Company, Ltd.	A-20	8
Oahu Sugar Company, Ltd.	A-14	3
	A-15	4
Olaa Sugar Company, Ltd.	A-11	1
	A-12	2
Onomea Sugar Company	B-19	11
Paauhau Sugar Plantation Company	P-2	26
Pepeekeo Sugar Company	B-19	11
Pioneer Mill Company	A-17	6
	A-19	7
	X-35	29
Union Mill and Plantation, Ltd.	Union M. F.	27
Waiakea Mill Company	Waiakea M. F.	28
	10-5-20	
Waianae Company	A-15	4
	A-21	9
Waimea Sugar Mill Company	A-17	6
	X-50 A	30

"A-11" ①

OLAA S. CO.

N	15	11.5 Am 3.0 Nitrate .5 Organic
P_2O_5	7	4 AmPhos 3 Bone
K_2O	15	Muriate & Nitrate
		37

"A-12" ②

OLAA S. CO.

N	15	11.5 Am 3.0 Nitrate .5 Organic
P_2O_5	5	2 Super 3 Bone
K_2O	18	Muriate & Nitrate
		38

"A-14" ③

OAHU S. CO.

N	7	6.0 Am .5 Nitrate .5 Organic
P_2O_5	20.5	3 Bone 17.5 AmPhos & Super
K_2O	17	Sulphate & Nitrate
		44.5

"A-15" ④

OAHU S.CO.
WAIANAE CO.

N	9	8.5 Am .5 Organic
P_2O_5	20	3 Bone 17 AmPhos & Super
K_2O	20	Sulphate
		49

"A-16" ⑤

KOLOA S. CO

N	11	10.5 Am .5 Organic
P_2O_5	40	3 Bone 37 AmPhos & Super
K_2O	0	—
		51

"A-17" ⑥

WAIMEA S.M.CO.
KEKAHA S.CO. PIONEER M.CO.

N	9.5	9.0 Am .5 Organic
P_2O_5	41.5	38.5 AmPhos & Super 3.0 Bone
K_2O	0	—
		51

"A-19" ⑦

PIONEER M. CO.

N	6.7	6.2 Am .5 Organic
P_2O_5	29.25	26.25 AmPhos & Super 3 Organic
K_2O	16	Muriate
		51.95

"A-20 ⑧

LIHUE P. CO.
KOLOA S. CO.

N	6.25	5.9 Am .35 Organic
P_2O_5	31.25	29.25 AmPhos & Super 2 Organic
K_2O	17.75	Muriate
		55.25

"A-21" ⑨

WAIANAE CO.

N	5	4.5 Am .5 Organic
P_2O_5	20	17 AmPhos & Super 3 Organic
K_2O	20	Sulphate
		45

"B-17" ⑩

HONOMU S.CO.

N	7.5	7.0 Am .5 Organic
P_2O_5	7.5	4.5 Super 3 Bone
K_2O	25	Muriate
		40

"B-19" ⑪

HILO S.CO. PEPEEKEO S.CO.
ONOMEA S.CO.

N	7.5	7.0 Am .5 Organic
P_2O_5	15	12 AmPhos 3 Bone
K_2O	25	Muriate
		47.5

"B-21" ⑫

HAWAIIAN AGRI.CO

N	9	Am
P_2O_5	20	AmPhos & Super
K_2O	10	Sulphate
		39

"B-25" (13)
HAKALAU P. CO.

N	10	9.5 Am .5 Organic
P_2O_5	7.5	4.5 AmPhos 3 Organic
K_2O	25	Muriate

42.5

"G-2" (14)
H.C. & S CO.

N	4	Am
P_2O_5	28	AmPhos & Treble
K_2O	15	Muriate

47

"HAMAKUA M.CO. H.G." (15)
HAMAKUA M. CO.

N	14.25	Am
P_2O_5	12.25	AmPhos
K_2O	14.5	Muriate

41

"H.S.-2" (16)
HAWAIIAN S. CO.

N	7.25	Am
P_2O_5	17.75	AmPhos & Super
K_2O	19.25	Muriate

44.25

"H.S.-3" (17)
HAWAIIAN S CO

N	13.25	Am
P_2O_5	33.40	AmPhos & Super
K_2O	0	—

46.65

"H.S.-4" (18)
HAWAIIAN S. CO.

N	8	Am
P_2O_5	32	AmPhos & Super
K_2O	16	Muriate

56

"HONOKAA A" (19)
HONOKAA S.CO.

N	15.26	Am & Nitrate
P_2O_5	13.44	Treble Super
K_2O	14.91	Nit. Potash

43.61

"HONOKAA B" (20)
HONOKAA S.CO.

N	15.47	Am & Nitrate
P_2O_5	9.13	Treble Super
K_2O	15.19	Nit Potash

39.79

"HONOKAA C" (21)
HONOKAA S.CO.

N	12.48	Am & Nitrate
P_2O_5	6.99	Treble Super
K_2O	11.93	Nit. Potash

31.40

"HONOKAA D" (22)
HONOKAA S. CO.

N	15.66	Am & Nitrate
P_2O_5	7.47	Treble Super
K_2O	14.91	Nit. Potash

38.04

"K-8" (23)
KILAUEA S.P. CO.

N	4.5	Am
P_2O_5	26.6	AmPhos & Super
K_2O	14.9	Muriate

46

"LAUPAHOEHOE S CO. MF" (24)
LAUPAHOEHOE S. CO.

N	11	Am
P_2O_5	8	Super
K_2O	20	Muriate

39

"P.S.5A" (25)
GROVE FARM CO.

N	.75	Organic
P_2O_5	21	4.25 Bone 16.75 Am Phos & Super
K_2O	18.75	Muriate
	40.50	

"P-2" (26)
PAAUHAU S.P.CO.

N	9.6	9.1 Am .5 Organic
P_2O_5	19.2	16.2 Super 3 Organic
K_2O	19.2	Muriate
	48	

"UNION M&P. LTD. M.F." (27)
UNION M.&P. LTD.

N	9.3	Am
P_2O_5	13.3	Am Phos & Super
K_2O	20.0	Muriate
	42.6	

"WAIAKEA M.CO. H.G." (28)
WAIAKEA M. CO.

N	10	Am
P_2O_5	5	Raw Rock
K_2O	20	Muriate

"X-35" (29)
PIONEER M.CO.

N	22	13 Am 9 Nitrate
P_2O_5	0	—
K_2O	29	Nitrate
	51	

"X-50A" (30)
KOLOA S.CO. KEKAHA S.CO.
WAIMEA S.M.CO

N	15.4	3.6 Am 11.8 Nitrate
P_2O_5	0	—
K_2O	40	Sulphate Nitrate
	55.4	

"X-56" (31)
KEKAHA S.CO.

N	13.5	Am
P_2O_5	0	—
K_2O	17.0	Sulphate
	30.5	

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD

SEPTEMBER 19, 1934, TO DECEMBER 14, 1934.

Date	Per Pound	Per Ton	Remarks
Sept. 19, 1934	2.865¢	$57.30	Cubas, 2.86, 2.87.
" 20	2.865	57.30	Cubas, 2.86, 2.87.
" 21	2.87	57.40	Cubas.
" 24	2.885	57.70	Cubas, 2.87, 2.90.
" 25	2.90	58.00	Cubas.
" 26	2.91	58.20	Cubas, 2.92, 2.90.
" 27	2.94	58.80	Cubas.
" 28	2.96	59.20	Cubas, 2.95, 2.97.
Oct. 1	2.99	59.80	Cubas, 2.98, 3.00.
" 2	3.00	60.00	Cubas.
" 4	2.9833	59.67	Cubas, 2.95, 2.98, 3.02.
" 5	2.93	58.60	Cubas.
" 8	2.93	58.60	Cubas.
" 15	2.95	59.00	Cubas.
" 17	2.905	58.10	Cubas, 2.90, 2.91.
" 18	2.89	57.80	Cubas.
" 22	2.82	56.40	Cubas, 2.79, 2.85.
" 29	2.81	56.20	Puerto Ricos, Cubas, 2.80; Cubas, 2.81, 2.82.
Nov. 7	2.86	57.20	Cubas.
" 16	2.92	58.40	Cubas.
" 19	3.00	60.00	Cubas.
" 20	3.085	61.70	Cubas.
" 30	2.80	56.00	Cubas.
Dec. 5	2.9375	58.75	Cubas, 2.90, 2.975.
" 6	2.975	59.50	Cubas.
" 13	2.63	52.60	Cubas.
" 14	2.63	52.60	Cubas.

THE HAWAIIAN PLANTERS' RECORD

Vol. XXXIX SECOND QUARTER, 1935 No. 2

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Cane Varieties:

The bearing of crop restriction on work with new cane varieties is discussed. It is pointed out that on several scores better cane varieties make claim for attention as a means of lowering the cost of production.

Irrigation:

A progress report is presented on the Waialua project of irrigation studies. Here we have a well-planned piece of work that seeks specific knowledge of the interrelated values that pertain to the application of water to the cane crop. These values vary with the type of soil. They vary with the method, amount and interval of application. They are influenced by the time of year and by the weather. Human judgment will always play a most important part in determining how and when to apply water to sugar cane fields; but there is little doubt but that by a better knowledge of the pertinent underlying values, such judgment will be materially strengthened and enhanced in practical value.

Studies on Growth of Sugar Cane in Nutrient Solutions:

The results of certain nutritional studies on the growth of the sugar cane plant that have been conducted in water and sand cultures during the past two years are presented. The following subjects are discussed: the effect of the pH value of the nutrient solution on sugar cane growth; cane growth in tap water and distilled water; cane growth in relation to acidity; the effect of varying amounts of manganese on sugar cane growth; sugar cane growth in aerated and non-aerated water cultures; the growth of Lahaina cane in aerated water cultures; and the supply of iron to the cane plant through two roots.

Phosphate Fixation:

The phenomenon of phosphate fixation in Hawaiian soils is discussed in connection with studies of the subject as conducted with the new Experiment Station

phosphate fixation outfit. A history of the development of the method is presented, together with its application to problems of fixation and fertilization. Examples are given showing the manner of employing the kit.

A Procedure for Testing Cane and Soil from the Same Areas:

A clear description is given of the way in which the Pioneer Mill Company plans to collect information bearing upon the important issue of differential fertilization for fields or parts of fields. In detail is presented the practical technique whereby each day cane, from measured portions of the areas harvested, will be weighed and kept apart for juice tests for phosphate and potash. Soil tests from the same areas are to be made by the rapid methods. There will result, during the 1935 crop, for purposes of correlative study from over 1,000 sample areas representing about 500 acres of cane land, information on yield per acre, quality of cane, and phosphate and potash content of both soil and cane juice. The plan impresses one as definitely progressive, reaching into the practical possibilities of differential fertilization in a manner both effective and comprehensive.

A Fertilizer Policy Based on Field Experiments:

The bearing of an extensive series of field experiments at the Pioneer Mill Company on the development of the present day fertilizer practices is set forth in a detailed way. The fertilizer question has been approached from the standpoint of the several soil types to be dealt with. The requirements of nitrogen, phosphates, and potash have been studied with regard to the maintenance of the proper degree of balance between these plant essentials. The field experiments have been supplemented by determinations of phosphates and potash in cane juice. The article forms a comprehensive review of a long and valuable program of work.

Present Trends in Fertilization:

Certain important points are brought out with respect to each of the three main plant foods in their relation to present trends in fertilizer practices, whereby the individual needs of individual areas is being closely sought.

Fertilizer Schedules:

By way of correcting our previous presentation, the fertilizer schedules of the Oahu Sugar Company are shown in better and more complete form.

Hogpens:

An improved type of pen for the hogs of plantation laborers is shown.

Variety Problems in Relation to Crop Restriction

In view of the fact that the Hawaiian sugar industry is already able to produce more sugar than it is permitted to ship under the present crop restriction measure, we are obliged to ask ourselves whether the program of cane breeding and seedling testing as it is now being carried on by the Station and by the plantations is justified, and if not, what changes are required to meet the new situation.

In the past it has been possible to combat rising costs by increasing production. This mode of defense has been particularly effective when an increased yield entails no increased expenditure, as when a good variety of sugar cane is replaced by a better one.

With production restricted by law, the center of interest shifts from the problem of profit or loss per acre to one of profit or loss per ton of sugar. What is the relationship of improved varieties to the new situation?

Fifty years ago the old Lahaina variety occupied nearly every acre of land devoted to sugar cane in the Territory. Had Lahaina not been replaced by superior canes it is doubtful whether the Hawaiian sugar industry would have survived its infancy. If the present emergency finds this industry equipped with reasonably satisfactory sugar cane varieties it is in consequence of the efforts which have been exerted toward this end during the past thirty years.

We may grant that the greater the economic pressure the greater the need for varieties capable of producing sugar at low cost. We are, nevertheless, obliged to face the fact that anything we may be doing today in the direction of developing superior canes can offer no hope of reducing the cost of the 1935 or even the 1936 crops. Considering only the results to be realized within the three-year restriction period, a good case could be made for a policy of discontinuing for the time being all effort and expenditures relating to variety testing. It is certain that immediate costs could be reduced by such a procedure. However, if it is true that the present varietal resources of the plantations are the results of past efforts, it is equally true that those of the future depend upon the efforts of today.

Cane Breeding Objectives Under Crop Restriction

The breeding program has had as its goal the development of varieties capable of producing a maximum profit per acre under the various conditions of the Territory. It may be of interest to consider whether the specifications to which a good cane must conform remain valid as the goal is shifted from one of maximum profit per acre to one of maximum profit per ton of sugar allotted.

Sucrose Content has a definite bearing on profit per acre. It is even more intimately related to profit per ton of sugar. Under crop restriction, therefore, it assumes increased importance.

The development of improved hand refractometers and convenient juice sampling punches has greatly facilitated the determination of juice quality in the testing of new seedlings. It is now feasible to obtain sufficient juice data to eliminate in the early stages of testing the seedlings which are subnormal in this respect.

High Yielding Ability: At first glance it might appear that under the new situation less importance is to be attached to high yield per acre since we now have at our disposal more acres than are necessary to produce the allotted tonnage. Upon closer examination, however, we are reminded that many of the costs connected with the growing of a cane crop are *per acre* costs. This category includes plowing, planting, irrigation, cultivation, and rentals. To a considerable degree fertilization costs are also per acre costs. The *per ton* cost of these items increases as the per acre yield decreases.

A rough calculation may serve to illustrate the point. Let us assume a figure of $100 per acre as the cost of cultivation, irrigation, and fertilization, and nine tons of sugar per acre as an average yield. One hundred thousand acres would then be required to satisfy a 900,000-ton quota. If, through the substitution of superior varieties, the average yield could be increased to 10 tons per acre, only 90,000 acres would be needed to produce this quota. The consequent elimination of 10,000 acres from cane cultivation, with costs at $100 per acre, would result in a saving of $1,000,000. This figure does not include the additional savings which result from concentrating the production on the more efficient lands. It is clear then, that high yielding ability remains an important consideration in cane breeding even under restriction.

Several other varietal characteristics which assume increased importance under crop restriction may be listed as follows:

Strong Ratooning, Fast Closing In: The superiority of certain of the new seedlings with respect to these qualities has been established by plantation experience. As compared with some of the seedlings of POJ derivation, H 109 must be classed as a relatively weak ratooner, slow in closing in, and often necessitating an undue amount of replanting. The POJ 2878 seedlings—31-1203 and 31-1389—are both superior to H 109 in these features.

A reduction of ten dollars an acre in replanting and weeding costs would save the industry over a million dollars a year. There can be no doubt that savings as large or larger than this will be realized when each acre in the Territory is planted to the variety best suited to its conditions.

Efficient Utilization of Soil Moisture and Plant Foods: Certain of the seedlings derived from hardy parentages are less exacting in their water requirements than are the older varieties. POJ 2878, for example, proved superior to H 109 under the conditions of water shortage which prevailed in central Maui during the past two years. 28-1864, a half-sister of POJ 2878, is superior even to the Java cane under the extremely dry conditions of the makai unirrigated lands of the Hamakua and Kohala districts. There are also indications that some of the newer seedlings may have the advantage of lower fertilizer requirements than the older varieties. Fertilizer experiments bearing on this question are now under way on some of the plantations.

Harvesting and Transportation Costs: In the past we have been obliged to resort to small-stalked canes of the Uba type on the poorer lands of the unirrigated districts because we had no canes of fair stalk size which possessed sufficient vigor to succeed under these unfavorable conditions. These small-stalked trashy canes are objectionable because of their high harvesting and transportation costs.

The crossing of POJ 2878 with Uba-H 456 blood now promises to give us a new race of seedlings which combine the hardiness of Uba with the large-stalk size, easy trashing and superior juices of the noble canes.

Plantation Policy Under Crop Restriction

To those of us who are concerned with the problem of developing better canes it is gratifying to note that crop restriction has brought about no abatement of interest in variety testing. Some of the unirrigated plantations have curtailed their planting as an economy measure. Almost without exception, however, these plantations have set aside fields for the testing and spreading of new seedlings of promise. The wisdom of such a policy is apparent. It is only by taking full advantage of this interim to test the available seedlings of promise and to build up a seed supply of those which have demonstrated their superiority that a proper choice of varieties can be made when the normal planting schedule is resumed.

A. J. M.

Notes on the Waialua Irrigation Investigations

By H. R. Shaw and J. A. Swezey

The realization of a high degree of irrigation efficiency, as reflected in a reduction of labor and in conservation of water, requires not only a knowledge of the gross requirements of the plantation as a whole but also an intimate knowledge of the water requirements of individual fields and of the demands of the cane plant, both in regard to quantity and time, for irrigation applications.

The Waialua Agricultural Company, Ltd., and the Experiment Station of the H.S.P.A. have undertaken a cooperative investigation with the object of adding to the knowledge of the irrigated plantations of Hawaii certain fundamental relationships between the sugar cane plant, the soil type, and the amounts and time of irrigation applications as studied under actual field conditions. This paper describes the plan and the early results of this investigation.

The plantation of the Waialua Agricultural Company, on the northern slope of Oahu, comprises normally 10,200 acres of irrigated cane land extending from sea level to an elevation of 750 feet. The residual volcanic soils above the 100-foot contour, about 68 per cent of the cultivated area, range in color from light red to dark brown, and are on an average slope of approximately 6 per cent. The remaining area, about 3,200 acres, on the coastal plain below the 100-foot contour consists of stream and marine alluvial deposits on an average slope of 2 per cent. The land surface of the entire area is cut by many deep gulches and dry ravines running in a general northwesterly direction. Prevailing winds are from the northeast. Rainfall averages 40 inches per year over the entire plantation. The distribution of rainfall is dominated more by the distance from the main ridge of the Koolau Mountains, extending from north to south at an elevation of 2,500 feet, than by altitude or other factors.

The entire plantation is under irrigation, averaging approximately 32 irrigations per crop of 23 months. More than 3,000 acres are entirely dependent on gravity water supplied from four watersheds having a combined storage capacity of 2,700 million gallons. The remaining area is supplied by steam and electric pumps with a combined output of 100 million gallons per day, supplemented for a portion of the year by gravity water. During periods of water shortage, and even of normal summer supply, the problems of efficient water distribution, frequency of application, and conservation of the gravity supply become acute.

In order to formulate an irrigation policy which would insure an adequate and proportionate distribution of irrigation water to all divisions of the plantations, three phases of investigational attack seemed necessary:

I. Measurement between divisions of the plantation of the water delivery on each supply canal in order to provide an exact and impartial basis for equitable distribution of the available supply.

II. A survey of the moisture-holding characteristics of the various soil types comprising the cultivated area of the plantation.

III. Field studies on the relation of soil moisture to the rate and extent of cane growth as influenced by soil type, weather variation, age of cane, and similar factors on various portions of the plantation.

I. Water Measurement

The program of water measurement has been in operation for two years. Measuring stations are situated at strategic points on each supply canal so that the delivery of irrigation water between plantation divisions is known at all times. Parshall measuring flumes equipped with water-level recorders are the type of control most generally used.

A water balance, showing the total irrigation water received, delivered, and consumed daily by each plantation division, is maintained. Weekly reports, giving the relation of area irrigated, water consumed, and number of men irrigating in each division, show the gross water requirement and labor efficiency in each area. In addition, measurements of water to selected field areas provide a guide to the net water requirements in various sections, and indicate the magnitude of seepage and evaporation losses between the point of delivery and entrance to the field.

II. A Survey of the Moisture-holding Properties of Plantation Soils

It is generally recognized that the ability of a soil to retain moisture is governed by the size and number of soil particles. A coarse-grained sand, for instance, will retain considerably less water than the finely divided soil particles of a clay or loam. It is perhaps not so widely realized that the same forces which tend to hold a greater amount of water around the soil particles also operate to withhold moisture from the action of surface evaporation and plant root feeding. Hence, although a clay soil will hold more moisture than the same volume of sand, the clay also holds moisture more strongly around the soil particles, and a greater proportion of the total soil water is unavailable to the plant.

Extensive experimentation on the mainland United States and in Hawaii has satisfactorily established the fact that each soil type has a definite capacity for water and an equally definite soil moisture percentage below which no plant is able to withdraw moisture at a rate sufficient to maintain normal growth. The upper limit of this zone of available soil moisture is commonly termed the Maximum Field Capacity; the lower limit is called the Wilting Percentage or Wilting Point. It is readily seen that a knowledge of the total amount of moisture in the soil at any time is valueless to the field man unless the amount of that water actually available to the plant is also known.

The problem involved in the second phase of the Waialua investigations was to determine the limits and amount of soil moisture available for plant growth in the various soil types represented on the plantation. The time and equipment which would have been required to make direct determinations of these factors on a sufficiently large number of samples to warrant confidence in the results were out of the question. However, it has proved possible to use a single-value soil moisture constant which may be obtained readily and inexpensively on a large number of

samples and which provides a direct measure of the relative moisture-holding properties of the soil and an indirect measure of the upper and lower limits of soil moisture available for plant growth. This constant, termed the Moisture Equivalent, has proved to be a rather sensitive and reliable index of the variation in physical properties of the soil not only over a wide range of soil types found in a large district but also in smaller variations occurring within a single field.

Some twenty-five years ago, investigators of the United States Department of Agriculture attempting to find a simple measure of the physical properties of soils, discovered that a consistent and reliable index of relative moisture-holding power was obtained by saturating small samples of soil, subjecting them to a constant centrifugal force in order to drive off excess water, and determining the per cent moisture retained by the soil. The same investigators learned, by determining the soil moisture percentage at the time various plants wilted, that for all soil types used in their investigation there was a constant and definite ratio between the soil moisture content at permanent wilting and the Moisture Equivalent. The ratio found in this first investigation on soils obtained chiefly from the Atlantic seaboard was 1.84, regardless of the species or age of plant used. Later investigations on the Pacific Coast demonstrated that, although the basic conception was sound, for soils of different origin and of different chemical composition the ratio of $\frac{\text{Moisture Equivalent}}{\text{Wilting Percentage}}$ might differ considerably from the simple 1.84 constant.

During the period 1928 to 1930, similar studies were made on the physical and moisture-holding properties of a number of widely different soil types from irrigated plantations on the islands of Oahu, Maui, and Kauai. For all soils studied, there was a remarkably consistent relationship between the Moisture Equivalent, the Maximum Field Capacity and the Wilting Percentage. This relationship may be expressed as:

$$\text{Maximum Field Capacity} = \text{Moisture Equivalent} \times 1.1$$

$$\text{Wilting Percentage} = \frac{\text{Moisture Equivalent}}{1.2}$$

It is now felt that for soils of similar origin or from similar geographic districts, the Moisture Equivalent may be considered a reliable index of soil moisture retentiveness and of the amount of water available to the plant in various soil types. Whenever possible, however, it is advisable to check by direct determination the per cent soil moisture retained by a soil shortly after irrigation and the per cent soil moisture at which plant growth is checked or handicapped by an inadequate supply of moisture.

In undertaking the plantation soil survey based on the Moisture Equivalent, each field was sampled soon after harvest. A road, ditch, or similar well-defined boundary was taken as a base line, and sampling points established every 300 feet at right angles to the base line. Truly random samples were thus obtained with one sampling point for each two acres of land. Separate samples of surface soil and subsoil were obtained at each point, and field notes on surface slope, soil color, etc., were recorded. The Moisture Equivalent determinations were made at the Waipio soils laboratory of the Experiment Station.

The results from the laboratory determinations were classified in the following arbitrary groups and charted on a map of the plantation:

Moisture Equivalent Class	Probable Value of Maximum Field Capacity	Probable Value of Wilting Percentage	Probable Range of Available Soil Moisture
25.0% and less	27.5% and less	21.0% and less	6.5% and less
25.0 to 30.0	27.5 to 33.0	21.0 to 25.0	6.5 to 8.0
30.0 to 32.5	33.0 to 36.0	25.0 to 27.0	8.0 to 9.0
32.5 to 35.0	36.0 to 38.5	27.0 to 29.0	9.0 to 9.5
35.0 to 40.0	38.5 to 44.0	29.0 to 33.5	9.5 to 10.5
40.0 to 45.0	44.0 to 50.0	33.5 to 37.5	10.5 to 12.5
45.0 and over	50.0 and over	37.5 and over	12.5 and over

The survey, which is now practically completed, has contributed valuable basic information on the variation of soil types over the plantation area. It has demonstrated that the area of the plantation may be divided into definite soil groups, determined by their origin and degree of weathering, each of which has definite characteristics of moisture retention and physical structure. (See Fig. 1.) Very briefly, these soil groups may be defined as follows:

Group I. *The Mountain Belt*—extending from the 550-foot contour to the upper limits of the plantation, and from Waimea to Kemoo. Characterized by high moisture-holding capacity, Moisture Equivalent value from 35 to 45 per cent, available soil moisture from 10 to 12 per cent. Deep and uniform as to depth and area.

Group II. *The Middle Belt*—extending from the 300-foot contour to the 550-foot contour, and from Waimea to Kemoo. Characterized by good moisture-holding capacity, Moisture Equivalent value from 30 to 35 per cent, available soil moisture from 8 to 10 per cent. Fairly deep and uniform on plateaus, rather shallow top soil and low retentiveness on palis and ridges.

Group III. *The Lowland Belt*—extending from the 100-foot to the 300-foot contours, and from Kawailoa to Kawaihapai. Characterized by low moisture-holding capacity, Moisture Equivalent value from 25 to 35 per cent, available soil moisture from 6.5 to 9.0 per cent. Evidence of erosion and shallow top soil throughout, very low retentiveness on ridges and palis. Marked by heavy rock deposits and diverse soil type distribution, especially in upper Ranch to Kawaihapai. Apparently the upper edge of an alluvial fan.

Group IV. *The Coastal Plain*—extending from sea level to the 100-foot contour and from Opaeula to Kawaihapai. Characterized by high moisture-holding capacity, Moisture Equivalent value from 35 to 45 per cent and greater, available soil moisture from 10 to 14 per cent. Chiefly alluvial deposits from uplands and marine deposits from old high-level seas. Variable depth and uniformity, often broken by old coral beds.

Group V. *The Beach Belt*—a limited and broken area close to sea level. Characterized by very low moisture-holding capacity, Moisture Equivalent value 25 per cent or less, available soil moisture 6.5 per cent or less. Chiefly old beach lines and coral outcrops.

Fig. 1. Soil map based on Moisture Equivalent survey indicating the ability of various soils to retain moisture.

It should be understood that this soil classification is not necessarily a reflection of the productivity or fertility of the areas described, but pictures rather sensitively the physical and particularly the moisture characteristics and limitations of the soil. Other things being equal, a soil in Group III might well produce as much or more sugar per acre as a soil in Group I or II, but it would require more frequent applications of water to maintain the same rate of growth.

The Moisture Equivalent survey provides an effective background and a useful tool in a number of plantation and general operations. It reflects remarkably well the generally accepted geological history of this district. It provides a basis for the rational distribution of irrigation waters based on the retentive capacity and the band of available soil moisture on various areas, and indicates localized areas within fields which require special irrigation treatment. Lastly, it establishes a basis by which the results of studies on the response of cane growth to water may be safely extended to similar soil types in larger field and divisional areas.

III. Field Studies on the Relation of Soil Moisture to the Rate of Cane Growth

The object of the third phase of the Waialua investigations is an attempt to learn more precisely the effect of weather variations, soil type, age of cane, and similar factors on the interval permissible between irrigation applications if uninterrupted growth is to be maintained.

The past fifteen years have seen considerable progress made both in more efficient methods of applying water to the land and in a more exact and scientific basis of distributing the water to fields. The early work of Allen at Waipio, the Waimanalo investigations, the Ewa type of interval test on Oahu, Kauai, and Maui, the Waipahu studies on soil moisture, and the Aiea investigations have all contributed to a keener understanding of the value of irrigation water as a growth factor under varying environmental and cultural conditions.

The Experiment Station of the H.S.P.A., during the past eight years, has undertaken studies of the fundamental relationships existing between the cane plant, water and the soil. The studies began with research in the laboratory and greenhouse on the physical nature and moisture properties of certain Hawaiian soils, and on the manner in which sugar cane and other plants grown in small containers responded to soil moisture under carefully controlled conditions. The results of these findings were then applied on a larger scale to cane grown to maturity in large tanks of soil in which moisture conditions could be kept under control and in which the response of cane growth to water throughout the life of the plant could be closely studied. Finally, the accumulation of evidence gained was applied to large field plots under natural conditions. The sequence of results was consistent and logical, and the basic principles which applied to small masses of soil and to immature plants in the greenhouse were demonstrated with the normal cane crop grown in the field environment. Naturally the final step in this series of progressive studies would be to apply the results of the experimental phases of the work to commercial utilization under plantation conditions and in large scale production. This application of experimental results is now being attempted in the third phase of the Waialua investigations now in progress.

The basic relationships which were well established in the experimental studies may again be summarized as follows:

1. Each soil type has a definite capacity for water, termed the Maximum Field Capacity. A unit volume of soil, after irrigation, cannot retain more or less than this definite amount. Hence, the most efficient irrigation is one which fills to Maximum Field Capacity the soil area to the depth of the feeding roots. A heavier application of water results in penetration below the root zone from which it may never be recovered; less water results in an inadequate supply to the deeper roots.

2. After irrigation cane growth is at a relatively constant rate, affected only by season and possibly by age of cane, until the soil moisture has been depleted by root feeding to a point commonly called the Wilting Percentage at which cane growth is definitely checked and is not resumed until additional water is added to the soil.

3. The value of the Wilting Percentage is dominated by the soil type and does not change with the species or variety of crop, the season or the age of the plant. Hence, the most efficient interval between irrigations is one which replenishes the moisture supply shortly before it is depleted to the Wilting Percentage.

4. In both pot experimentation and in field tests, it has been impossible to detect from the appearance of the soil surface or from the appearance of the leaves or stalk of the cane plant when the Wilting Percentage has been reached. Generally the plant shows no obvious signs of requiring additional water for from five days to a week after growth has stopped.

5. Under certain conditions of high temperature, low relative humidity, and high wind velocity, plants may exhibit all the signs of wilt and inhibited growth that normally result from inadequate soil moisture. Such cases of temporary wilt are due to the rate of transpiration or water withdrawal being greater than the power of the roots to replenish the supply. Cane growth is resumed when the severe weather conditions are reduced.

The field studies of the Waialua project are not experimental in the sense that one treatment is compared with another. The lengths of from 10 to 20 stalks of cane are measured frequently and carefully at 19 field stations within normal commercial field areas on the plantation. The stations are located at key positions extending from one extreme of the plantation to the other and from sea level to 750 feet elevation, embracing diverse combinations of soil type, elevation, exposure and cane age. At seven stations, soil moisture samples are frequently obtained in close proximity to the measuring stations. The rate of cane growth and the rate of soil moisture depletion, with various indices of weather and environmental conditions, are plotted throughout the year.

One of the chief advantages of this type of investigation over the formal field experiment in which results are based solely on yields obtained at the end of the crop, is that it is possible to apply the information gained from cane and soil moisture measurements directly and immediately to the general field practice. Thus, it has been possible to utilize the early results, both of the Moisture Equivalent and the Cane Growth studies, in the actual plantation irrigation policy and practice within six months of the time the investigation started. The Moisture Equivalent

is used as a guide in determining, (1) how soon certain field areas are to be irrigated after a general rain, (2) to what general areas heavier or faster irrigation rounds should be made, and (3) to some extent, what marginal areas may be eliminated from production because of low moisture-retaining characteristics. The growth studies are already proving of value in indicating the frequency of irrigation necessary on certain soil areas at various times of the year, the proper balance between irrigated area and normal water supply, and the probable loss of growth resulting from inadequate irrigation applications.

The results of the first nine months of the investigation have shown considerable promise in the substantiation of the basic principles of soil moisture and plant growth determined experimentally. The results justify confidence in the Moisture Equivalent as a measure of the physical nature of the soil and as an indirect determinant of the upper and lower limits of available soil moisture. The conception that cane growth, for the period between irrigations, is at a constant rate unless the soil moisture is depleted below the Wilting Percentage of the soil has been substantiated; as has the belief that the Wilting Percentage is a function of the soil type and does not vary with increasing age of cane or with different seasons.

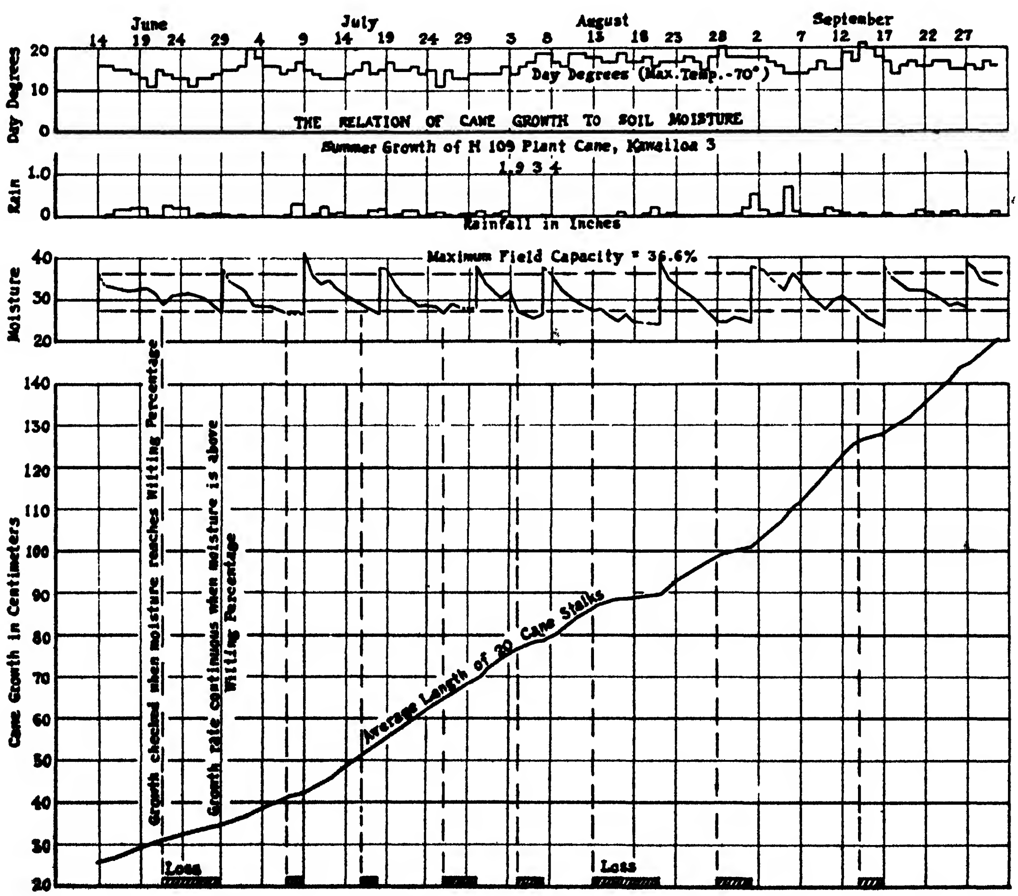


Fig. 2. Uninterrupted cane growth is dependent on maintaining the soil moisture above the Wilting Percentage.

COMPARISON OF THE WILTING PERCENTAGE OBSERVED IN THE FIELD WITH THE VALUE COMPUTED FROM THE MOISTURE EQUIVALENT OF THE SOIL

Field	Waimea 3			Kawailoa 3			Gay 7			Opaeula 13			Mill 2			Helemano 2A		
Moisture Equivalent	38.8			33.3			33.5			41.8			36.1			35.3		
Computed Wilting Pct. M. E. ÷ 1.2	32.3			27.8			27.9			34.8			30.0			29.4		
				Observed Wilting Percentages														
1934	Date	Per Cent Soil Moisture	Interval (Days)	Date	Per Cent Soil Moisture	Interval (Days)	Date	Per Cent Soil Moisture	Interval (Days)	Date	Per Cent Soil Moisture	Interval (Days)	Date	Per Cent Soil Moisture	Interval (Days)	Date	Per Cent Soil Moisture	Interval (Days)
MAY				23	29.4	5												
JUNE	14	32.9	19	13	27.5	18												
				22	29.7	8	22	27.8	9									
JULY	3	35.3	15	7	27.0	8	12	27.8	9									
				16	28.8	7												
	20	34.3	8	26	27.0	8	20	29.2	6				28	32.4	14			
AUGUST	7	32.3	10	4	27.0	5	8	27.0	6	9	34.6	4	7	31.6	7			
				13	27.3	6												
	23	33.2	12	28	24.7	7	28	26.7	11									
SEPTEMBER				14	27.4	13	16	27.5	8	12	37.8	15						
				26	29.1	9				29	36.6	12	24	31.9	12			
OCTOBER				8	28.3	11	5	27.8	11	17	33.5	13	10	31.1	12	10	29.9	12
NOVEMBER				3	29.3	9	5	26.7	9				8	32.0	12			
							24	29.7	15									
DECEMBER				12	28.0	21	18	27.0	20							14	29.9	24
AVERAGES		33.6			27.9			27.7			35.6			31.8			29.9	
Divergence from Computed Value	+1.3			+0.1			—0.2			+0.8			+1.8			+0.5		

The type of data obtained may best be illustrated graphically by the relation between cane growth and the zone of available soil moisture, determined, indirectly from the Moisture Equivalent of the soil, in a field of plant H 109 cane during the summer of 1934 (Fig. 2). The Moisture Equivalent of this soil is 33.3 per cent, which gives an indirect value of 36.6 per cent for the Maximum Field Capacity and a value of 27.8 per cent for the Wilting Percentage. These limiting values are plotted as horizontal lines in the upper center of the graph. Total soil moisture percentages are plotted against the dates on which they were obtained during the summer. It may be seen that the rise of soil moisture due to irrigation, shown as a vertical line on the moisture chart, on only one occasion (when rainfall added free water to the soil at the time of sampling) reached a value more than two per cent greater than the computed Maximum Field Capacity, and repeatedly rose only to the predicted limit and no higher.

The lower curve shows the successive lengths of 20 stalks of cane as they were measured throughout the summer. It may be demonstrated by holding a straightedge against any period of growth that the rate of growth is continuous as long as the soil moisture is above the Wilting Percentage. The point at which the continuous rate of growth is checked, shown as a vertical dotted line connecting the growth curve and moisture curve, is obviously the point at which the soil moisture is reduced to the predicted value of the Wilting Percentage. The curves also demonstrate that growth is resumed at a normal rate as soon as additional water is added to the soil.

Table I compares the observed Wilting Percentage at six field stations with the computed Wilting Percentage as obtained indirectly from the Moisture Equivalent of the soil. The average values for all observations made in each field are within two per cent of the predicted value, and at four of the six stations the divergence is well under one per cent.

Summary

1. The plan and early results of a cooperative irrigation investigation undertaken by the Waialua Agricultural Company and the Experiment Station of the H.S.P.A. are contained in this progress report.

2. The investigation is divided into three phases: (a) measurement and gross distribution of irrigation waters, (b) a survey of the moisture-holding properties of the plantation soils, and (c) field studies on the relation of soil moisture to cane growth.

3. The survey of plantation soils is based on the Moisture Equivalent, a physical constant of the soil which may be readily obtained. On the basis of results from this survey, the plantation soils have been divided into five groups, each of which has definite characteristics of moisture retention and physical structure.

4. The field studies on the relation of soil moisture to cane growth are the application to commercial field areas of eight years of experimental research by the Experiment Station. The basic principles established in the laboratory, greenhouse, and field experiments have been satisfactorily substantiated during the nine months in which the field studies have been conducted.

5. Evidence from the field work is offered to show that a given soil type will hold only a definite amount of water, that cane growth is at an essentially constant rate after irrigation until the soil moisture has been depleted to a critical and constant value called the Wilting Percentage, after which normal cane growth is not resumed until additional water is added to the soil.

6. Data are presented to show that the limiting values of this zone of available soil moisture may be indirectly determined with considerable precision from the Moisture Equivalent of the soil.

7. The project is proving to be sound in principle, simple and inexpensive in design and operation, and is bringing immediate returns on the investment.

Bibliography

Allen, R. M., 1918. The relation of soil moisture to irrigation. The Hawaiian Planters' Record, Vol. XVIII, pp. 295–304.

Beveridge, T. K., 1927. Irrigation investigations at Waimanalo. The Hawaiian Planters' Record, Vol. XXXI, pp. 138-154.

Briggs, L. J., and McLane, J. W., 1910. Moisture equivalent determinations and their application. Proceedings American Society Agronomy, Vol. II, pp. 138–147.

———, and Shantz, H. L., 1912. The wilting coefficient for different plants and its indirect determination. U.S.D.A. Bureau Plant Industry, Bulletin 230.

Penhallow, R., 1932. Determining the irrigation requirements of sugar cane and adjusting field practice to meet these requirements at Honolulu Plantation. Reports of the Association of Hawaiian Sugar Technologists, pp. 71–98.

Renton, George F., and Alexander, W. P., 1926. An investigation to determine the relation of irrigation water to maximum sugar yields. Proceedings of the Hawaiian Sugar Planters' Association, pp. 36–95.

Shaw, H. R., 1929–1931. Soil moisture constants of Hawaiian soils. H.S.P.A. Project A-4

———, 1930. Studies on the response of cane growth to moisture. Reports of the Association of Hawaiian Sugar Technologists, pp. 127–147.

———, 1930. Field studies on the water response of cane. H.S.P.A. Project A-3.

———, 1932. Plantation interval tests. The Hawaiian Planters' Record, Vol. XXXVI, pp. 323–335.

———, and Wadsworth, H. A., 1929–1931. Water requirements of the cane plant. H.S.P.A. Project A-8.

Stewart, G. R., 1925. Irrigation investigations at Waimanalo. The Hawaiian Planters' Record, Vol. XXIX, pp. 384–398.

Veihmeyer, F. J., Israelson, O. W., and Conrad, J. P., 1924. The moisture equivalent as influenced by the amount of soil used in its determination. University of California, Agricultural Experiment Station, Tech. Paper 16.

———, and Hendrickson, A. H., 1928. Soil moisture at permanent wilting of plants. Plant Physiology, Vol. III, pp. 355–357.

———, and ———, 1931. The moisture equivalent as a measure of the field capacity of soils. Soil Science, Vol. XXXII, pp. 181–193.

———, Oserkowsky, J., and Tester, K. B., 1927. Some factors affecting the moisture equivalent of soils. Proceedings and Papers, First International Congress of Soil Science, Vol. I, Comm. I, pp. 512–534.

Wadsworth, H. A., 1934. Soil moisture and the sugar cane plant. The Hawaiian Planters' Record, Vol. XXXVIII, pp. 111–119.

———, and Das, U. K., 1930. Some observations on the wilting coefficient of a selected Waipio soil. The Hawaiian Planters' Record, Vol. XXXIV, pp. 289–299.

Studies on Growth of Sugar Cane in Nutrient Solutions

By J. P. Martin

The growth response of plants to various chemical treatments is often studied under greenhouse conditions in either sand or water cultures. By using chemically pure salts and distilled water it is possible to grow plants in different media of known chemical composition and observe the effect of a special treatment upon their growth.

The sugar cane plant, like many other plants, has been successfully grown in nutrient solutions which contain the elements essential for normal development. By altering the nutrient solution, definite effects are induced in the cane plant and by this procedure, the deficiency symptoms of nitrogen, potassium, phosphorus, calcium, etc., may be studied by omitting that particular element from the basic nutrient solution. Various staff members of this Experiment Station have demonstrated by the use of sand and/or water cultures, that in certain instances an abnormal development of the cane plant in the field is caused by a faulty nutritional soil condition, e. g., Pahala blight which is caused by a manganese deficiency.

The object of this paper is to record some of the nutritional studies of the cane plant that have been carried out in water and sand cultures during the past two years. The results of each experiment recorded herein have been given briefly in the Director's Monthly Report but in most cases without illustrations. In these experiments, two different nutrient solutions were used and will be referred to from time to time as nutrient solution "A" or "B." The partial volume molecular concentrations per liter of the chemically pure salts in each solution follow:

	Solution "A"	Solution "B"
$Ca(NO_3)_2.4\,H_2O$	.009	.003
$Ca\,Cl_2.\,2\,H_2O$	....	.004
KH_2PO_4	.0045	.001
$K\,NO_3$	....	.003
$Mg\,SO_4.7\,H_2O$	.0045	.001
$H_3\,BO_3$	.00002	.00002
$Na_2SiO_3.9\,H_2O$	.00001	.00001

In each solution, iron was added at the rate of 10 parts per million (p.p.m.) from ferrous ammonium sulphate, while manganese was supplied at the rate of .25 p.p.m. from manganous sulphate.

Experiment 1

The Effect of the pH Value of the Nutrient Solution on Sugar Cane Growth:

Favorable cane growth has been obtained in "complete" nutrient solutions which have been prepared with distilled water. The cost of distilling water becomes an important factor to consider when large volumes are used. For certain experimental work it is not necessary to use distilled water for the preparation of

Fig. 1. Showing cane growth in nutrient solution "A" prepared with tap water (containers A and B), boiled tap water (containers C and D) and distilled water (containers E and F). Note growth failure of plants in solutions prepared with tap water and boiled water (A, B, C, D). Normal growth resulted with solutions prepared with distilled water (E and F).

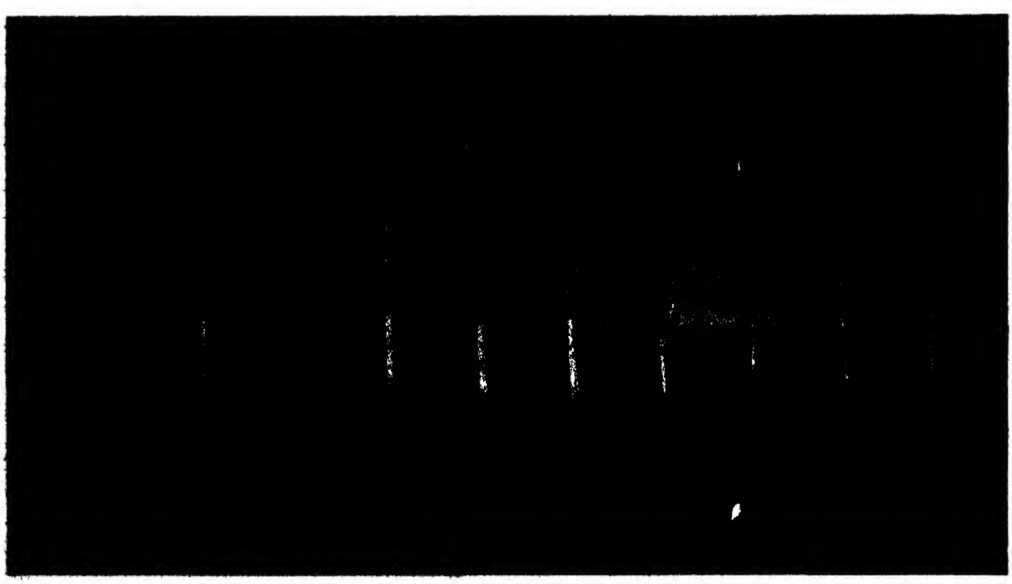
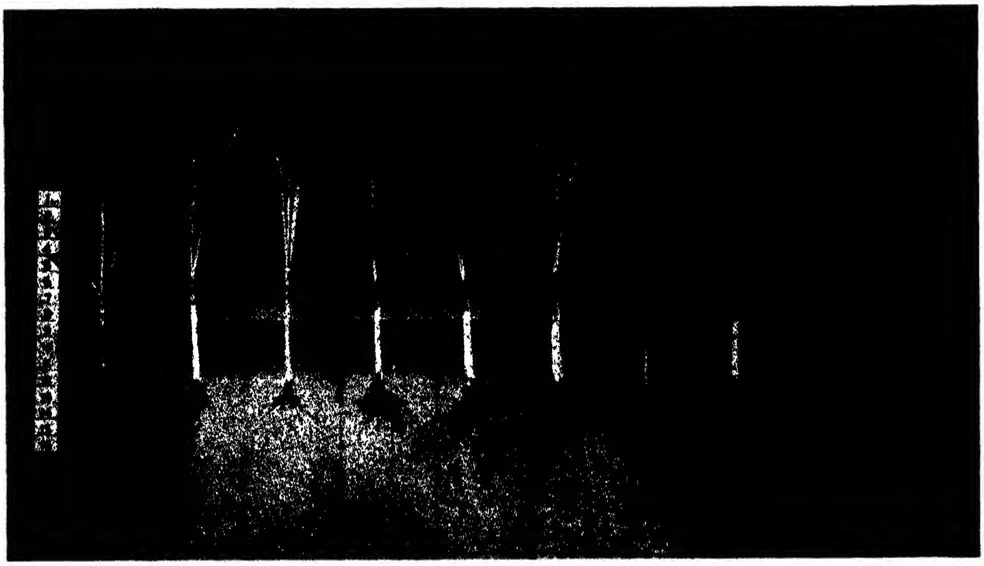


Fig. 2. Showing growth failure of plants in nutrient solution "A" prepared with tap water. Age of plants, 78 days. The plants failed to grow and many died; the root systems were poorly developed, short and stubby, and badly affected with root rot disease.



H 109(2)   D 1135(2)   POJ 2878(2)   Yel. Cal.(2)   POJ 36(1)   Lah.(1)

Fig. 3. The plants in nutrient solution "A" prepared with boiled tap water failed in a manner similar to those shown in Fig. 2. Note the dead and chlorotic tops on several varieties and the poorly developed root systems on all plants. These symptoms are similar to those of iron deficiency.

H 109(2)   POJ 2878(2)   POJ 36(2)

Fig. 4. Showing the contrast of plant growth in nutrient solution "A" prepared with distilled water and boiled tap water. The roots which developed in the latter were severely injured with root rot, badly discolored and manifested an iron deficiency type of growth which is characterized by short, stubby roots. The plants in the same nutrient solution prepared with distilled water produced a normal growth.

the nutrient solutions. In this experiment, studies were made of cane growth in nutrient solutions prepared with tap water and distilled water.

In these studies, shoots from germinated cuttings of the following varieties were used: H 109, POJ 2878, Yellow Caledonia, D 1135, POJ 36 and Lahaina. One plant of each of the first four varieties and one of either POJ 36 or Lahaina were placed in a five-gallon earthenware jar and held in an upright position by placing two halves of a large cork around each plant and then fitting the cork and the plant as a unit tightly into a circular hole in a wooden cover (Fig. 1).

The purpose of placing five varieties in a single pot was to have each variety receive identical treatment. With this arrangement, any differences that developed in a single treatment might readily be interpreted as varietal response rather than as some conditional factor. This method has certain advantages over the method where each plant is grown in an individual container.

Shortly after the plants were placed in nutrient solution "A" prepared with tap water, the leaves began to manifest definite symptoms of iron deficiency. Later, the leaves showed acute iron deficiency symptoms; the roots developed a distorted or "stubby" type of growth, also characteristic of iron deficiency; and many of the roots were badly rotted by the fungus *Pythium graminicolum.* At the end of 6 weeks the majority of the plants either exhibited a total growth failure or were dead.

Prior to the death of the plants, almost every root had become soft or flaccid as a result of root rot. In order to determine the relation of *Pythium* root rot to the growth failure of the plants, another angle to this experiment was designed, after discussing the problem with C. W. Carpenter, wherein tap water, boiled tap water, and distilled water would be used for preparing the nutrient solutions. It was thought that the *Pythium* fungus might be present in sufficient quantities in tap water to cause an acute rotting of the roots. In view of this possibility, tap water in one series was to be boiled before using so that the *Pythium* factor might be eliminated.

In this phase of the work, two five-gallon containers with a similar arrangement of plants were used in each of the three treatments. The leaves of the plants in the nutrient solutions prepared with tap water and boiled tap water soon began to show symptoms of chlorosis. The growth of the plants was greatly retarded and the root development was extremely weak (Figs. 1, 2, 3 and 4). The majority of the plants were dead at the end of from 6 to 8 weeks, and the growth failure of the plants agreed in every respect to that previously described.

The cane plants in the nutrient solution prepared with distilled water produced a normal growth and the roots were exceptionally healthy (Fig. 5).

The nutrient solutions prepared with distilled water were found to be more acid than those prepared with tap water, the former having a pH value of 5.0 to 5.2, and the latter, a pH value of 5.8 to 6.0. Since the plants in the tap-water solutions manifested definite symptoms of iron deficiency, it was thought that due to the alkalinity of the solution, the iron was changed to insoluble ferric hydroxide and the failure of the plants was caused by an iron deficiency.

In further studies cane plants were grown in nutrient solution "A," which was prepared with tap water and adjusted to a pH value of 5.0 to 5.2 by the addition

H 109(2) D 1135(2) POJ 2878(2) Yel. Cal.(2) POJ 36(1) Lah.(1)

Fig. 5. Showing the normal growth of plants in nutrient solution "A" prepared with distilled water. The pH value of the solution was 5.0 to 5.2, whereas that prepared with tap water or boiled tap water was 5.8 to 6.0. Note the healthy top growth and root development of the plants in contrast to those in Figs. 2 and 3.

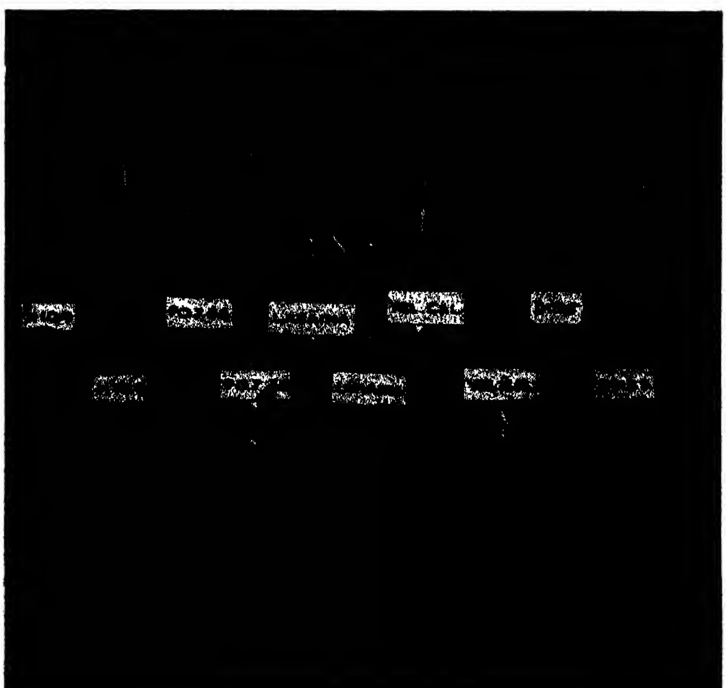


Fig. 6. The large plants were grown in nutrient solution "A" prepared with tap water and adjusted to a pH value of 5.0 by adding sulphuric acid. The small plants were grown in a similar nutrient solution which was not acidified; these plants manifested acute iron deficiency symptoms before they died.

of sulphuric acid, and in a similar solution which was not adjusted or acidified. In the acidified tap water cultures the plants made a normal growth, whereas in the unadjusted tap water solutions the plants again failed in a manner similar to that already described. The marked differences between the adjusted and unadjusted tap water cultures on cane growth are shown in Fig. 6.

The results of these experiments demonstrate that the pH value of the nutrient solution should be approximately 5.0 to 5.2 in order to maintain the iron in a form which is available to cane plants, and if tap water is used for preparing the nutrient solutions it is necessary to adjust the pH value accordingly.

The pH value of ordinary tap water at the Experiment Station when these tests were being conducted was found to be 7.8 to 8.0 while that of distilled water was from 6.8 to 7.0. The addition of the chemicals to the distilled water in preparing the nutrient solutions raised the acidity or changed the pH value from 7.0 to between 5.0 and 5.2 which proved favorable for cane growth. However, when the same chemicals were added to tap water, the solution became more acid but only to the pH value of 5.8 to 6.0 which proved unsatisfactory for normal cane growth; when the pH value was adjusted to 5.0 or 5.2 by the addition of sulphuric acid, the iron at this acidity was in the form of ferrous sulphate which is soluble and readily available to the plants.

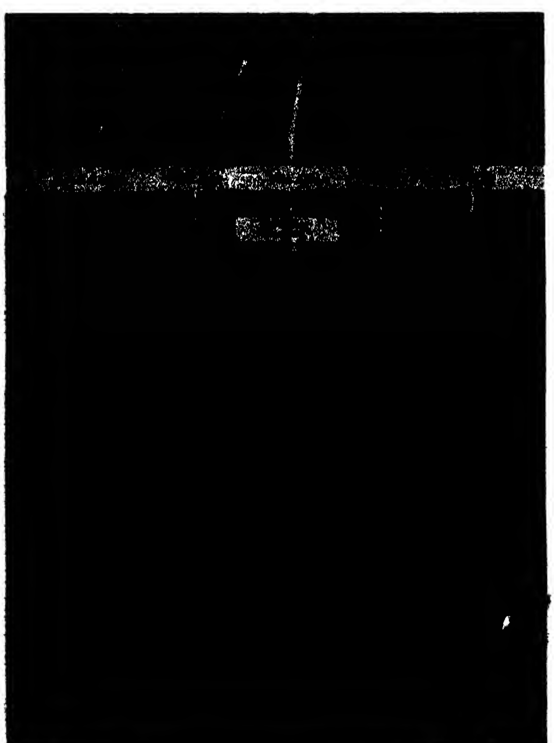


Fig. 7. Sugar cane plants at the age of 3 months that have been grown entirely in tap water. The plants made a slight top growth and only a moderate root development during this period. The leaves were at all times chlorotic.

Experiment 2

Cane Growth in "Standing" Tap Water, "Running" Tap Water and in Distilled Water:

Since water is the most essential element for sugar cane development, it was considered desirable to study the type of cane growth produced from young shoots when grown in tap water and in distilled water.

Young shoots of a uniform size were selected from germinated cuttings of the varieties Lahaina, POJ 36, Yellow Caledonia, D 1135 and H 109. One shoot of each variety was placed in a five-gallon earthenware jar and held in an upright position similar to the method described in Experiment 1. In the following experiment no nutrients other than those in the water itself were supplied to the plants.

The cane plants in each of two containers received the following treatments:

A. Standing tap water—where ordinary tap water was supplied to the plants and changed once a week.

B. Running tap water—where a constant supply of tap water was supplied at the bottom of each container and allowed to overflow near the surface of the jar. In this test the plants were at all times in contact with slowly circulating tap water.

C. Distilled water—where distilled water was supplied to the plants and changed once a week.

The plants in the standing tap water treatment failed to make any appreciable growth during the experiment. The leaves were of a light greenish color which suggested nitrogen deficiency. The roots of each variety made a fair development in comparison to the top growth; however, they were small in diameter and lacked vigor but were comparatively free from disease. The top growth and root development of each variety are shown in Fig. 7. The pH value of the tap water was 7.7 to 8.0 but after it had remained in contact with the plants for one week it was found to be 6.8. The reduction in pH may be explained by the release of carbon dioxide (CO_2) by the roots.

In the running tap water the plants manifested a slightly better growth than those in the standing tap water, possibly due to the constant supply of water which contained small amounts of plant nutrients. The leaves exhibited rather definite symptoms of iron deficiency. The roots were greatly depressed in growth, small in diameter and moderately affected with root rot. The roots were also stubby in growth which is one characteristic of iron deficiency. The growth of the plants at the end of the experiment is shown in Fig. 8. The pH value of the water was approximately 8.0, and since a continuous flow of water was supplied to the plants at all times the pH value remained unchanged.

In the distilled water treatment the plants made no top growth whatsoever and the leaves were chlorotic in appearance, but such results would be expected from a medium lacking nutrients. The root development indicated that the plants possibly obtained small quantities of nutrients from the water itself but more probably they utilized the nutrients which they held in reserve at the beginning of the experiment. The roots were small in diameter, somewhat stubby in growth and

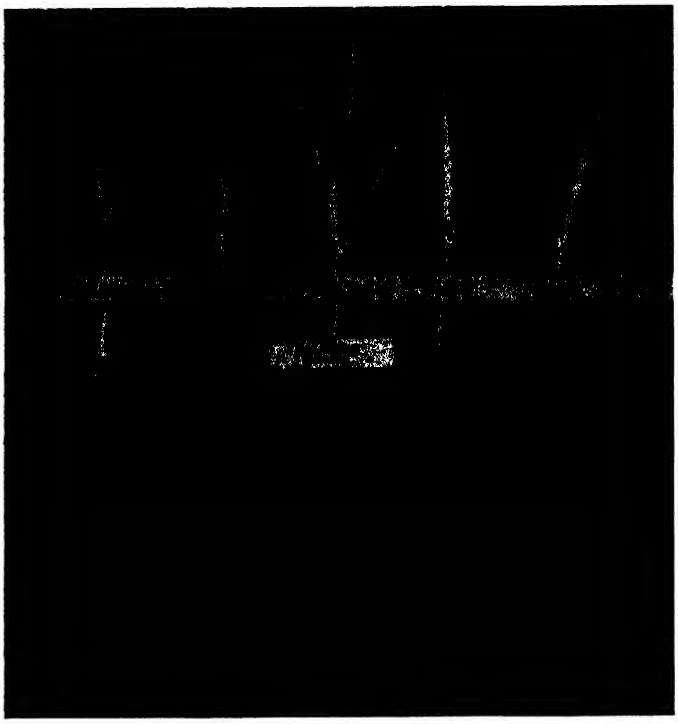


Fig. 8. Young sugar cane plants failed to make any appreciable growth in tap water which was slowly flowing at all times. The top development of the plants was similar tc that shown in Fig. 7, but the root systems were very much less and assumed a short, stubby type of growth. Age of plants, 3 months.

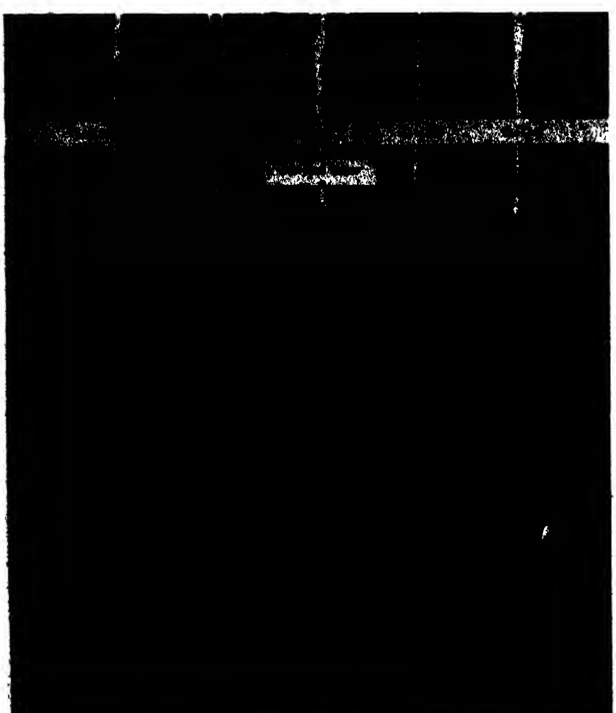


Fig. 9. When young cane plants were placed in distilled water they failed to make any further top growth but did develop fair root systems. Age of plants, 3 months.

free from disease. The volume of roots was slightly greater than in the other two treatments. The development of the plants in distilled water is shown in Fig. 9.

The above test was repeated with similar results. From these experiments it is evident that young cane plants are unable to make any perceptible growth in tap water or in distilled water alone.

Experiment 3

Cane Growth in Relation to Acidity:

At the suggestion of H. P. Agee, an experiment was conducted in water cultures for the purpose of studying the growth of the sugar cane plant in culture solutions of different pH values or different acidities.

Young plants which were obtained from germinated cuttings of H 109 and POJ 2878 were grown for five weeks in nutrient solution "B." During this period all plants made a very uniform growth. The pH value of the solution was from 5.0 to 5.2, i.e., slightly acid.

On November 7, 1933, plants of a uniform size were transferred to complete nutrient solutions the pH values of which were adjusted to 2.0, 3.0, 4.0 and 5.0 respectively by the addition of sulphuric acid. Sufficient sulphuric acid to maintain the desired pH value was added daily to each series.

The solution having a pH value of 2.0 proved toxic to plant growth. The plants made no further growth; the leaves developed a yellowish color, and the roots became flaccid and badly discolored. At the end of five weeks the plants were dead.

At pH 3.0 cane growth was greatly retarded. The majority of the roots became flaccid and discolored. The tips of the older leaves died prematurely and the blades were marked by alternating brownish and green stripes. In further studies this particular striping has been definitely associated with acid injury. The plants, however, remained alive but made no appreciable growth at this acidity.

The plants in the solution maintained at pH 4.0 continued to make a good growth throughout the test and no leaf symptoms of acid injury appeared.

In the medium which was adjusted and maintained at a pH value of 5.0, the plants produced the maximum growth and at all times appeared to be exceptionally healthy.

This experiment was started November 7, 1933 and was completed January 12, 1934. The growth response at the four different acidities is shown in Fig. 10. The higher acidities, namely pH values of 2.0 and 3.0, proved detrimental to the development of the plants, whereas the plants made a normal development in the solutions which were less acid.

Experiment 4

The Effect of Varying Amounts of Manganese on the Growth of Sugar Cane:

Pahala blight of sugar cane, which is caused by a manganese deficiency in the plant, is recognized by the presence of alternating dark green and narrower chlorotic-to-white stripes on the leaves. Definite symptoms of Pahala blight may readily

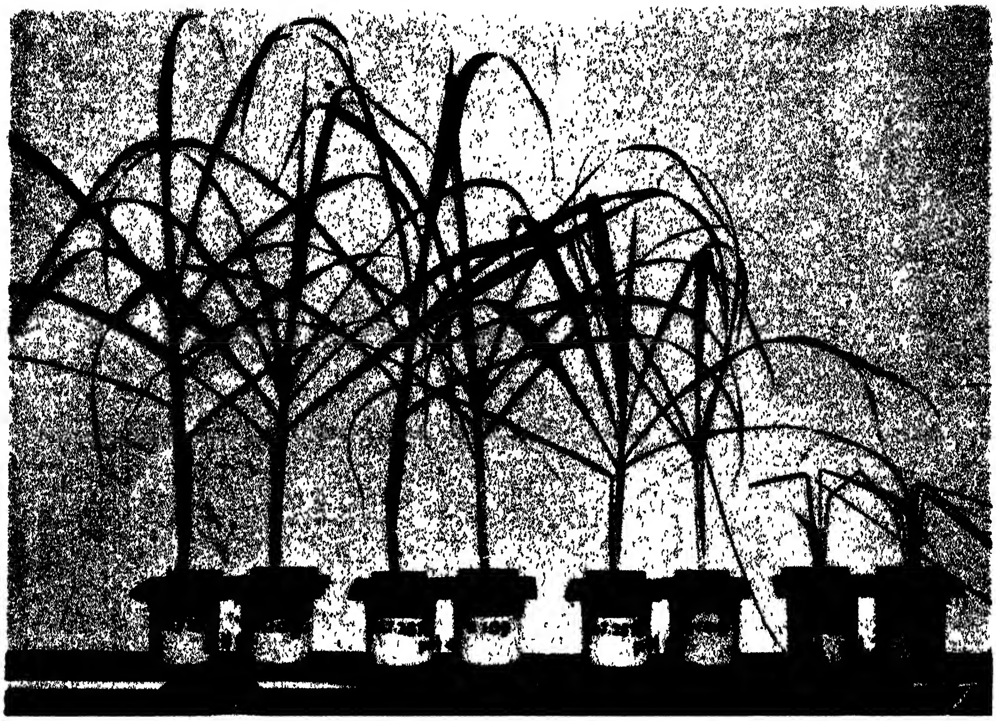


Fig. 10. Showing the effect of varying degrees of acidity on sugar cane growth. At pH 2.0, the plants soon died; at pH 3.0, growth was greatly retarded; at pH 4.0, fairly good growth resulted, while at pH 5.0, normal growth was obtained.

be produced by growing cane plants in a manganese-free nutrient solution. It has been demonstrated that an extremely small quantity of manganese is essential for normal cane growth.

Since the lack of manganese has a very definite detrimental effect on the cane plant, it occurred to the writer that it would be interesting to determine the effect of high amounts of manganese on the development of sugar cane.

In these studies H 109 cane plants were grown in nutrient solution "B" for a period of five months. Iron was added to the nutrient solution at the rate of 10 parts per million (p.p.m.) from ferrous sulphate, while manganese was supplied from manganous sulphate at the rate of .25 p.p.m. The plants at the end of this period were 6 to 7 feet in height and growth appeared normal in every respect.

On September 18, 1934, plants of a uniform size were placed in nutrient solutions wherein manganese was added at the rate of .25, 10, 20, 40 and 80 p.p.m. respectively. At the end of four weeks a pale striping similar to the early symptoms of iron deficiency appeared on the young leaves of the plants receiving 20, 40 and 80 p.p.m. of manganese. The striping was most conspicuous on the plants in the higher concentrations of manganese.

At the end of the fifth week the alternating dark green and chlorotic stripes were very definite on all plants which were receiving 10, 20, 40 and 80 p.p.m. of manganese. Within 8 weeks the young leaves were uniformly chlorotic and the plants receiving the three higher concentrations of manganese were depressed in growth (Fig. 11). The plants receiving .25 p.p.m. of manganese developed nor-

mally, and the roots were exceptionally healthy and vigorous. The roots on the other plants were badly discolored and rotted (Fig. 12).

The chlorotic condition of the plants which developed only at the four higher concentrations of manganese was in every respect similar to iron deficiency. It is very likely that the iron in the nutrient solution was oxidized to ferric oxide in the presence of the high amounts of manganese, and since ferric oxide is insoluble, the plants were unable to obtain sufficient iron for their normal development. This explanation is offered merely as a tentative theory and further studies are to be conducted in order to check this hypothesis. The cause of ratoon chlorosis in sugar cane, especially on the red soils which are known to have a high iron content, may be due to a temporary tying up of the iron in the presence of high amounts of manganese in the soil.

Experiment 5

Sugar Cane Growth in Aerated vs. Non-Aerated Water Cultures:

Plant growth in nutrient solutions is greatly improved when air is slowly bubbled through the solutions. In the writer's experience with sugar cane plants grown in nutrient solutions, excellent growth has been the rule for three or four months; following this period the roots gradually become discolored and show evidence of root rot. The deterioration of the root systems is comparatively slow at first but in time the roots are often severely injured. The severity of the injury usually varies directly with the variety grown, since certain varieties are more resistant than others to root rot disease.

In order to study the effect of aerating water cultures on cane growth, the following experiment was conducted. Ten five-liter percolator jars were held in an upright position by a specially constructed stand as shown in Figs. 13 and 14. All jars were filled with nutrient solution "B." Air supplied from a pressure tank was permitted to bubble slowly through the first five jars (Fig. 14). The flow of air entering the bottom of each jar was regulated by a glass stopcock. In this test young shoots of a uniform size from germinated cuttings of POJ 2878 and H 109 were used. Shoots of POJ 2878 were placed in the first two jars of the aerated and non-aerated series, while H 109 shoots were placed in the three remaining jars of each series. The young plants were held in wooden covers with the aid of large corks (Fig. 14). Each jar was covered with heavy black roofing paper in order to exclude light.

From the very start of the test the plants in the aerated cultures showed the better development. Within a month the roots of both varieties in the aerated cultures were considerably longer than those in the unaerated cultures. The solutions were changed once a week and toward the latter part of the experiment, additional solution was added to the jars in order to maintain a more constant volume of liquid so that the upper roots would not become dry. At the end of three months a marked difference was apparent between the top growth and root development of the plants in the two treatments. This difference became more marked as the experiment was continued. After seven months the experiment was terminated, the differences being shown in Figs. 13, 14 and 15.

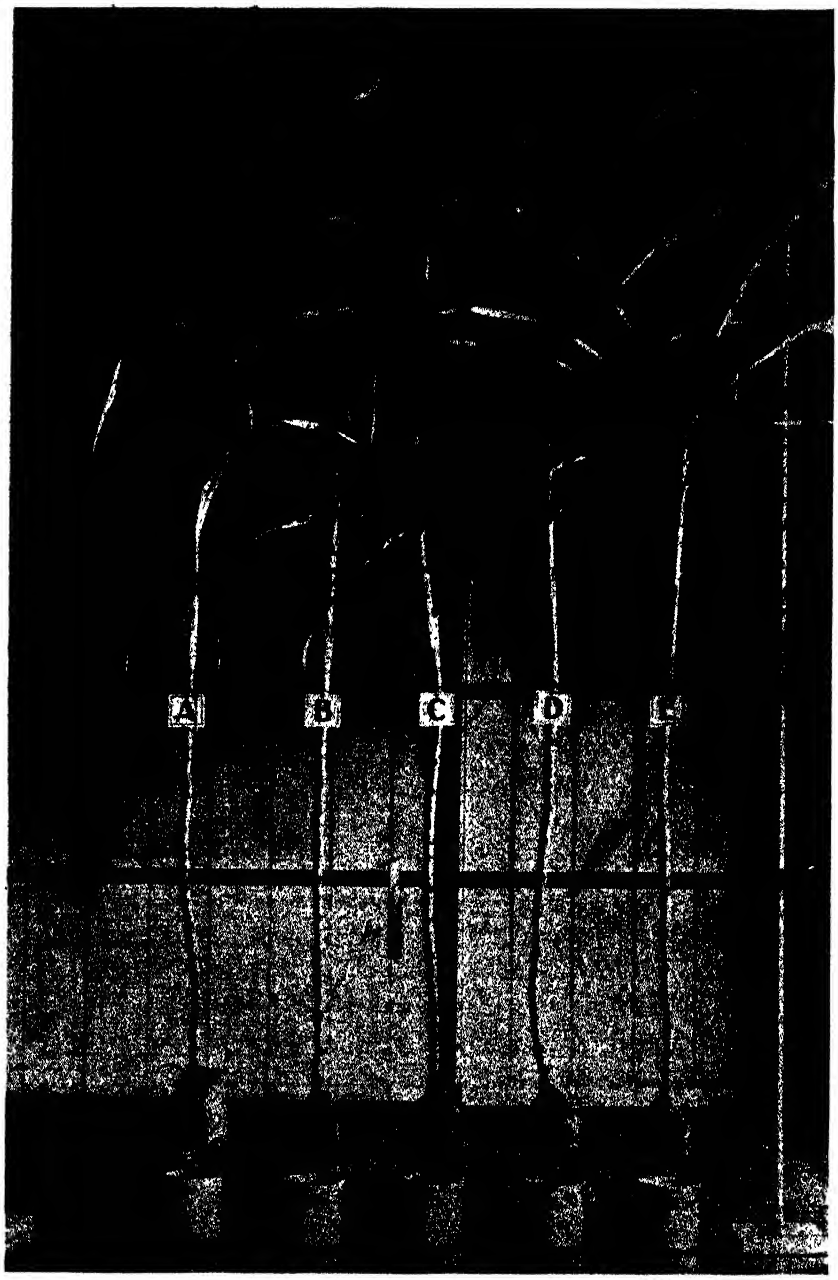


Fig. 11. H 109 cane plants A, B, C, D and E were grown in nutrient solution "B" to which were added respectively, .25, 10, 20, 40 and 80 parts per million of manganese. Normal growth resulted in the solution which received .25 p.p.m. The plants in the other four treatments manifested definite symptoms of iron chlorosis which increased in severity with increased amounts of manganese.

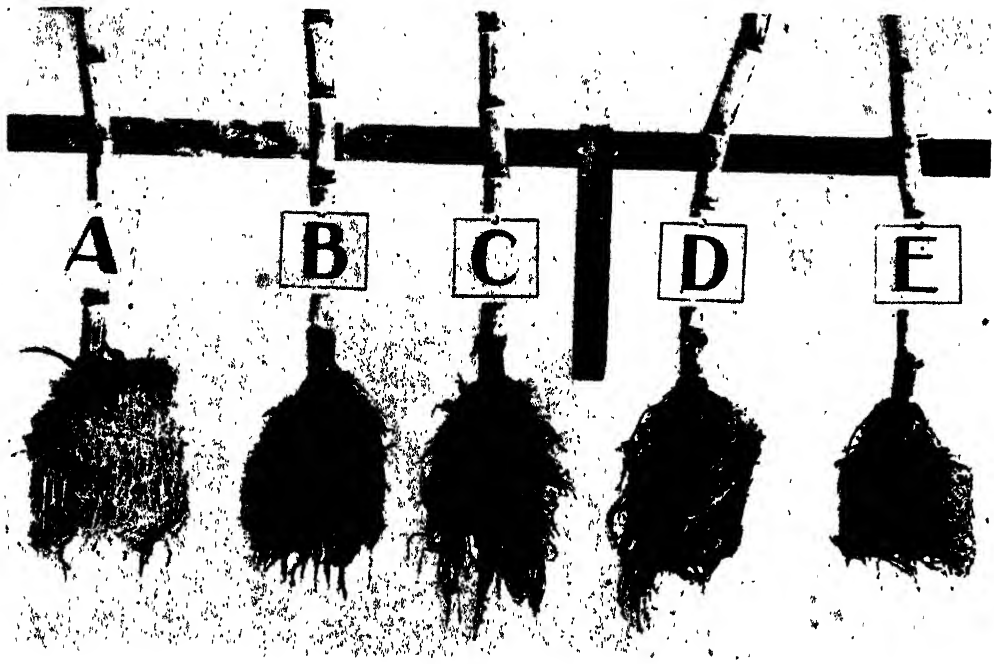


Fig. 12. The root systems of H 109 cane plants shown in Fig. 11. Note healthy appearance of root system A in contrast to the others which are badly discolored and affected with root rot disease.

In the aerated cultures the diameter of the stalks and the height and color of the plants were superior to those in the non-aerated solutions (Figs. 13 and 14). A marked difference in root development between the two treatments (Figs. 14 and 15) appeared to be very significant. The roots in the aerated cultures remained healthy and showed only traces of root rot, while the roots in the non-aerated solutions were severely affected with root rot as shown in the photographs. In the non-aerated solutions the roots of the POJ 2878 plants made a better growth than those of the H 109 plants and were less injured by root rot.

This experiment shows that a much superior growth in every respect was obtained in the aerated solutions. Subsequent tests have also shown that other varieties produce a much better growth in nutrient solutions which are aerated. The fact that the amount of root rot was so markedly reduced in the aerated cultures makes the method extremely valuable since root rot in water cultures is often the limiting factor for growth. It is impossible to study the effects of a particular treatment on the cane plant when root rot is severe.

Experiment 6

Growth of Lahaina in Aerated Water Cultures:

Young shoots from germinated cuttings of Lahaina were placed in one-gallon earthenware containers which were filled with nutrient solution "B." These solutions were aerated during the growth of the plants by allowing air under low pressure to enter the bottom of the container and slowly bubble through the solu-

AERATED — NOT AERATED
POJ 2878(2) H 109(3) POJ 2878(2) H 109(3)

Fig. 13. All plants received nutrient solution "B." The solutions in which the first five plants were grown were aerated, while those in the remaining five containers were not aerated. Note the superior top growth and root development of the plants grown in the aerated solution.

AERATED — POJ 2878(2) — H 109(3)

NOT AERATED — POJ 2878(2) — H 109(3)

Fig. 14. The stalks of the plants in the aerated culture solutions were the larger. The root systems were exceptionally free from root rot in contrast to the severely injured root systems in the non-aerated solutions.

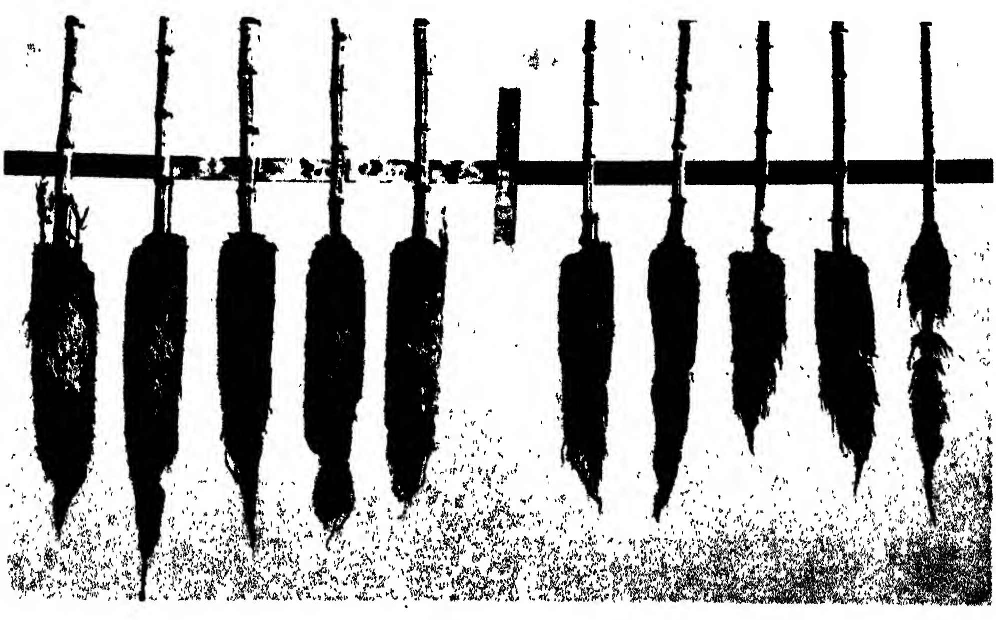


Fig. 15. Showing the root systems of the plants which were grown in aerated and non-aerated culture solutions, after being removed from the glass percolator jars.

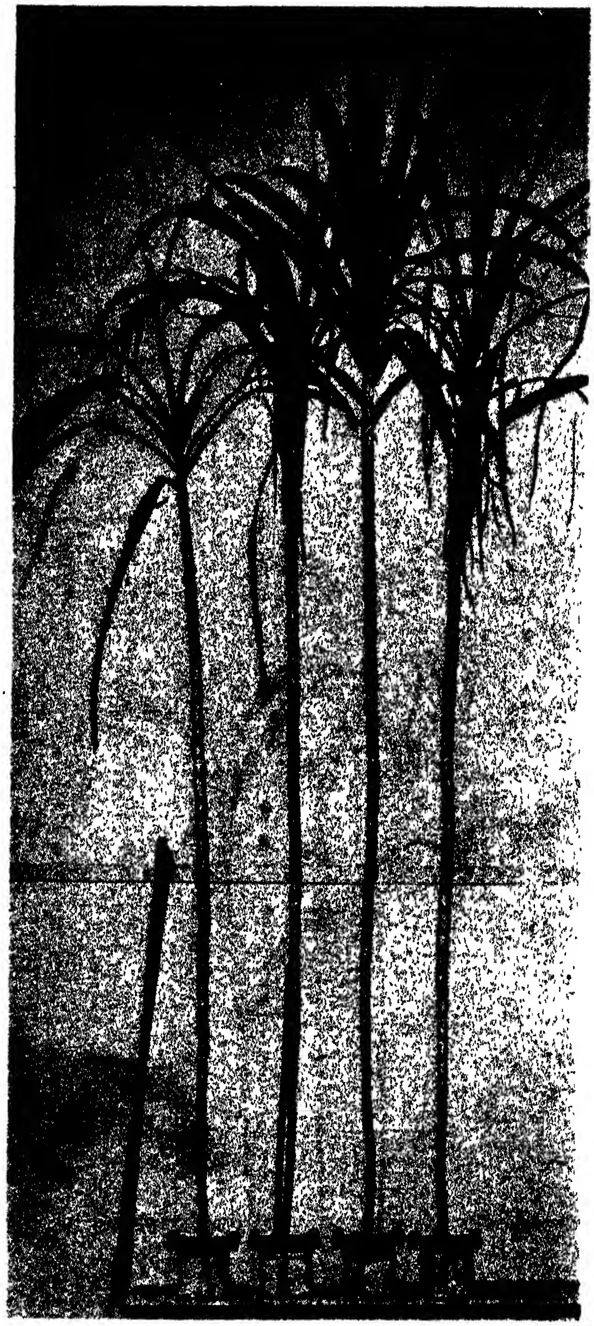


Fig. 16. Lahaina plants grown in nutrient solution "B" which was aerated. At the age of 10 months these plants were 12 to 14 feet in height and 1½ to 2½ inches in diameter. This growth was produced in one-gallon earthenware jars.

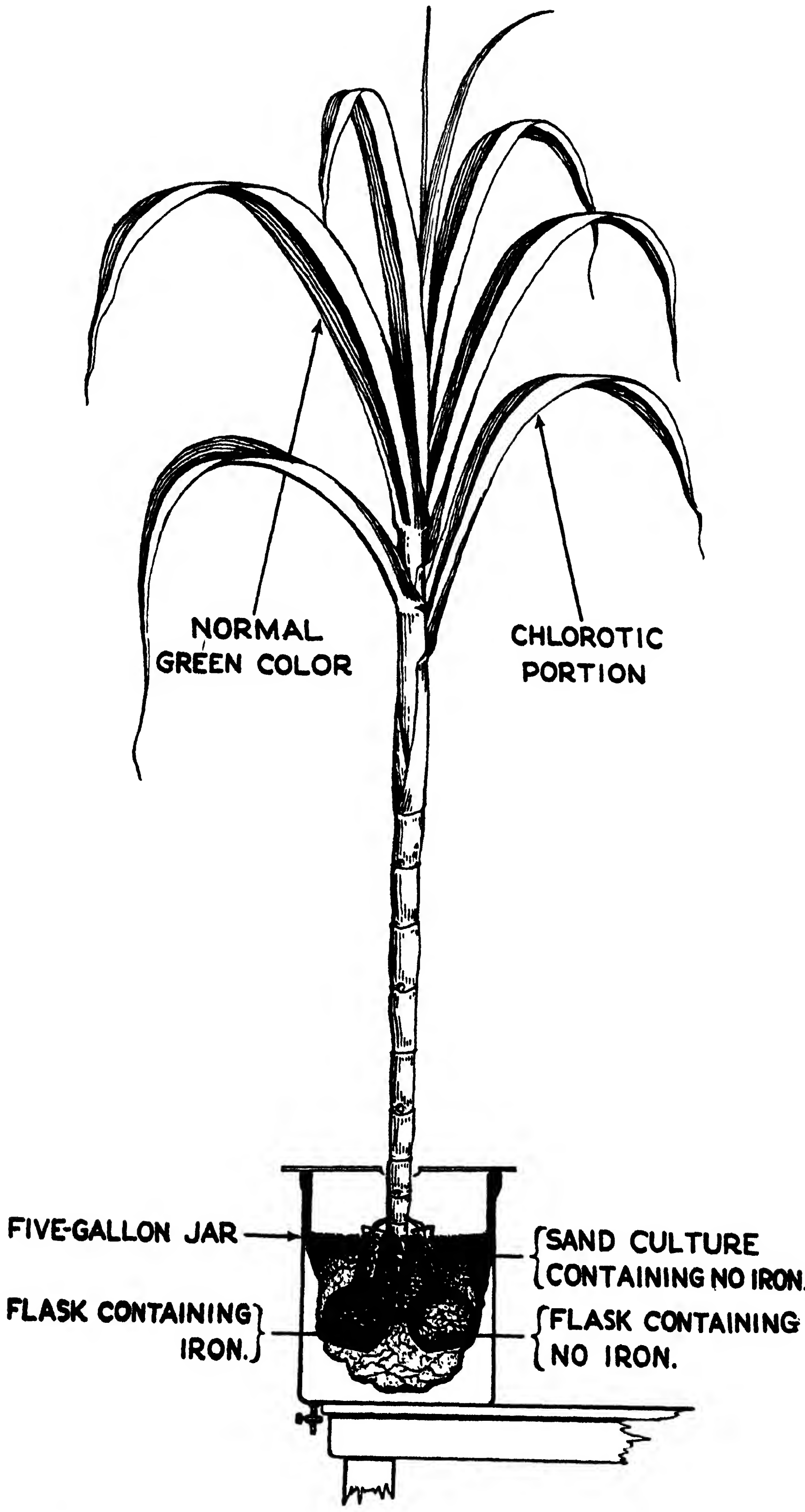


Fig. 17. When a chlorotic H 109 cane plant was supplied with iron through two roots, the normal green color developed only on the half of each leaf on the side supplied with iron.

tion. The flow of air into each jar was regulated by a glass stopcock; the amount of air being bubbled through the solution in each jar was observed by having the air bubble through an auxiliary container or flask before entering the opaque plant container (Fig. 16).

The plants made a normal growth at all times and at the end of ten months were from 12 to 14 feet in height with a stalk diameter varying from 1½ to 2½ inches (Fig. 16). This test demonstrates the excellent cane growth that may be obtained in small containers, and also shows that aeration of water cultures has desirable features. The plants in this test are the largest ones grown to date by the writer and they were still alive and growing three months after the photograph, Fig. 16, was taken.

Experiment 7

Supplying Iron to the Cane Plant Through Two Roots:

On January 10, 1934, iron was withheld from two H 109 cane plants, five feet in height, which had been growing in sand irrigated with nutrient solution "B." Very definite symptoms of iron deficiency soon appeared on the young leaves. In the meantime roots were induced to develop from a node slightly above the surface of the sand by keeping this region of the plant moist.

The leaves of the cane plant are borne in two ranks on opposite sides of the stalk, lying approximately in the same plane. Two roots developing on one side of the plant and at right angles to the plane of the leaves were directed into a 500 cc. flask which at the beginning of the experiment had been buried in the sand. Two other roots from the same node but on the opposite side of the plant were treated in a similar manner. Each flask was placed so that its mouth was one inch above the surface of the sand thus preventing the solutions within the flasks from coming in contact with the sand culture. The side roots detoured into the flasks were grown in an iron-free solution. The arrangement of this test is shown in Fig. 17.

By March 10, 1934, the plants manifested very definite symptoms of iron deficiency, the young leaves being uniformly chlorotic. On this date iron at the rate of 10 parts per million was added to the nutrient solution in one flask in order to learn whether or not as few as two roots could take up sufficient iron for the normal growth of the entire plant. Within 5 days a partial greening of the chlorotic leaves was apparent. This greening was not over the entire leaf as might have been expected but appeared only on the halves of the leaves on the side of the plant from which developed the two roots receiving iron. At the end of 14 days the half of each leaf on the side supplied with iron was of a normal green color from the base to the tip, while the portion on the other side of the midrib remained chlorotic. The contrast between the normal and the chlorotic half of each leaf was very striking (Fig. 17).

The above experiment was repeated and similar results were obtained. From these tests, which demonstrate that individual roots may supply specific regions of the plant with nutrients, several interesting theories have been advanced regarding the uptake and distribution of nutrients within the plant. The supply of plant nutrients through individual roots and its significance or application to field practice has been a subject for discussion.

Phosphate Fixation in Hawaiian Soils—IV Rapid Methods for Determining Capacity, Rate, Degree and Differentiation of Fixation

By Francis E. Hance and Q. H. Yuen

The phenomenon of phosphate fixation in soils is recognized, we believe, as having practical significance in sugar cane agriculture. When occurring in a moderate degree, fixation may be looked upon as a benefit to the farmer, for it then becomes a means of withholding the nutrient against leaching. However, when fixation is excessive and an application of water-soluble phosphate becomes so firmly held in the soil that plants may have difficulty in obtaining quantities necessary for growth and development, then phosphate starvation may be looked upon as inevitable.

It has been found to be generally true in Hawaiian soils that the capacity to absorb soluble phosphates varies in rate and degree with the individual soil. In papers by Davis (2), Ayres (1) and Hance (4) which have appeared previously in this journal, these findings are discussed in detail and relevant experimental data are offered.

The Development of the First Experiment Station Rapid Fixation Assembly:

Early in the course of our general research upon soil phosphate fixation, the Director of this Experiment Station, H. P. Agee, and the senior author of this paper undertook the development of a kit-like ensemble embracing a simple and straightforward means of evaluating phosphate fixation in any soil by employment of procedures on a miniature scale identical in scope and kind with actual field fertilizer practice. Cognizance was made of the fact that fixation occurs in the field only as a result of absorption of applied soluble phosphates by the soil in the presence of soil moisture and subject to the influences of natural phenomena. It became patent, then, that factors to be considered by the investigator for laboratory study need embrace but the simple essentials—soil, fertilizer and moisture—for under field conditions where an application of phosphate fertilizer may become "fixed," these primary materials only are involved. Furthermore, it was recognized that any ensemble or kit which might be developed for evaluating soil phosphate fixation must be simple in design and fool-proof in operation to be fully reliable and equally effective in the hands of an inexperienced as well as in those of a trained operator.

It was in September of 1932 that the first satisfactory kit was developed and put into use. After subjecting the original ensemble to careful study and critical trial, about 25 additional kits were built and stocked in our laboratories and later distributed among interested plantation workers.

The kit consisted of a case stocked with graduated bottles, funnels, filter papers, necessary reagents and a set of color standards. The bottles were of two-ounce liquid capacity, sufficient to hold 5 grams of soil and 30 cc. of fixation solution.

The reagents, other than the fixation solution, were ammonium molybdate and stannous chloride. These were employed in the test to produce the characteristic blue coloration indicative of phosphate concentration in the leachate following the fixation of applied phosphate in the soil under study. One pint of fixation solution comprised the reagent of greatest bulk. It consisted of a phosphate fertilizer dissolved in distilled water and adjusted to a concentration equal to 100 parts per million of phosphate calculated as P_2O_5. The principles involved in the determination are discussed later in more detail.

In general, laboratory tests for phosphate fixation follow the principle of adding a definite amount of the nutrient to a soil the phosphate concentration of which is known, and then after fixation is completed, of removing the phosphate remaining unfixed. The soil is then analyzed for phosphate. The final concentration in the soil minus the initial concentration will represent the amount fixed. However, in actual laboratory practice difficulties arise in the removal of unfixed phosphate which render the scheme impractical. An alternative is to determine the concentration of a solution of phosphate before and after passing it through a soil, fixation having taken place in the meantime. The difference between the initial and the final concentration of phosphate in the solution is the amount fixed by the soil. This latter method is employed in the Experiment Station rapid fixation test.

The procedure initially adopted involved the adding of a known amount of soil to a neutral phosphate solution of definite concentration. The soil was shaken with the solution and allowed to stand overnight; then the mixture was filtered. Reagents (ammonium molybdate and stannous chloride) were added to the filtrate which developed a blue color, the intensity of which was approximately proportional to the phosphate remaining in solution. By comparing the color developed in the filtrate with that of a series of standards the fixation capacity was ascertained and the results tabulated in arbitrary numerical indices ranging from 0 to 90, with step intervals of 10. The lighter the color, the greater the removal of phosphate from the solution by the fixation process and hence higher the fixation.

The limits of shade variations in the color standards used for this work were established by designating the maximum blue color developed in a 100 parts per million phosphate solution as "0" and that pale shade produced in a solution containing only a mere trace of phosphate as "90." The deep blue "0" index then, in a test would obviously indicate little or no fixation as having taken place, whereas the "90" index would indicate maximum measurable absorption of phosphate and hence would be indicative of very high fixation. The range of color shades between these two extremes, i.e., "0" and "90," was divided into eight convenient gradations. A total of ten graded shades of blue was thus made available by this arrangement. Numerical indices were assigned to these variations. Placed in convenient tubes in a rack sliding through an illuminated field, these graded colored solutions comprise the standards of reference used in the measurement of fixation indices.

It is recognized that fixation of phosphate in the soil may result in the formation of insoluble phosphates of the available form, or of a difficultly available form, or perhaps both. The phosphate may become insoluble through precipitation and yet may remain available to a greater or lesser extent. Experiments of cane feed-

ing with certain insoluble phosphates have been successfully conducted by members of the staff and later reported by Hance (4). In addition to this form of fixation, another may take place in which a larger proportion of the nutrient may be tenaciously withheld from utilization by the plants. Fixation of this latter type has been reported by Davis (loc. cit.). The usual laboratory methods of determining availability of phosphate in the soil have involved extractions with dilute acids. Solutions of phosphate in acid media are generally used in the study of fixation, as exemplified by the method of Demolon and Barbier (3).

The procedure used in the rapid kit method does not entirely ignore approved laboratory convention, except insofar as the fixation is brought about in a non-acid treatment and only in the presence of water, soil and a phosphate fertilizer. Rather than attempting to differentiate between the two forms of fixation mentioned above, the kit ensemble was designed to measure the fixation capacity of the soil by duplicating on a miniature scale the operations involved in field practice. The treatment of a soil with a neutral solution of phosphate may be considered as comparable in general to the application of fertilizer followed by irrigation. This method of employing a neutral fixation solution tends to maintain natural conditions of acidity or alkalinity in the soil as it may have existed before a phosphate fertilizer was introduced. Little or no re-solution of phosphate, already present in the soil, should occur in such a treatment and as a consequence the initial concentration of the fixing solution may be considered as practically unaltered, thereby contributing to the simplicity of the operation. Complications due to solubility effects or to other altered soil condition through the use of an acid treatment are at the same time avoided.

Relationships Between Fertility and Fixation:

Experiences of agriculturists have indicated that for Hawaiian soils, fertility with respect to phosphate fixation appears to be associated in most cases with the degree of fixation. Data obtained by the rapid kit method of analysis appear to be particularly applicable to such a consideration. From his researches on the mechanism of fixation, Davis (loc. cit.) has found that for many Hawaiian soils, the theory of fixation by precipitation with calcium, magnesium, iron, aluminum and titanium does not account for all of the fixation which may take place. Davis advances the theory of absorption to account for the maximum fixation occurring in upland Hawaiian lateritic soils. Ayres (loc. cit.), using refined laboratory procedure, has obtained results which lead, with certain exceptions, to conclusions similar to those enumerated above regarding the association of soil fertility with phosphate fixation. He found, however, that the matter of fertility did not correlate with propensity of fixation for some soils of the island of Hawaii. High fixation, as determined by present laboratory methods in certain exceptional soils, was not found as being correlated directly with low productivity.

The Fixation Solution:

The fixation solution used in the rapid kit method is prepared from diammonium phosphate, adjusted to neutrality and buffered so that filtration may be fa-

cilitated. In the original test the solution had a concentration of 100 parts per million of phosphate calculated as P_2O_5. The ratio of solution to soil was adjusted so that 30 cc. of phosphate solution would be brought in contact with 5 grams of soil (equivalent to a treatment of 1,500 pounds of P_2O_5 per acre-foot, 2.5 million pounds of soil). Following the simple kit procedure as already described, soils have been analyzed in this laboratory and also by plantation workers, generally with satisfactory results. The entire range of fixation (indicated by indices 0 to 90) has been encountered in the course of the many determinations which have been made.

The Development of the New Fixation Assembly:

It was found by ourselves and plantation workers that, in the ranges from low to moderate fixation, the kit method using the 100 parts per million P_2O_5 solution gave entirely satisfactory differentiations. However, when highly fixing soils were encountered, the procedure did not furnish a sufficiently sharp differentiation of the degrees of fixation in these higher registers. The amount of phosphate used in the original kit appeared to be entirely fixed in such cases so that for extreme fixations the index of "90" became applicable to all these determinations thereby creating an apparent similarity of degree of high fixation in a great number of soils which were suspected of being widely divergent in fixation capacity. A means of refining the kit operations in respect to differentiation was given additional study by Mr. Agee and the senior author. It was recognized that differentiation of fixation in any given series of soils should be rendered easy of recognition by the investigator in *all* the ranges of fixation which may be encountered in plantation field study. A modification of procedure was planned based entirely upon the principles involved in designing the original kit. An adjunct to the kit was developed which would in no measure occasion any deviation in procedure from the standard manner already in use for determining fixation and recording the findings. The modification consisted essentially of the employment of supplementary soil treatments in which an extended use was made of more concentrated phosphate fixation solutions. After preliminary trials, additional solutions containing 500 and 1000 parts per million phosphate were selected for the supplementary kit.

These solutions were prepared from the same materials as were used for the single original fixation solution (100 parts per million of phosphate as P_2O_5). The reaction (pH) was adjusted to neutrality and the solutions were buffered to insure satisfactory filtration. It has been found in some cases that in using these more concentrated solutions a pale yellow tinge may be imparted to the test solution after fixation has occurred and filtration of the test solution has been made. The coloration is due to presence of organic matter. However, the final results are not adversely affected.

Laboratory study using the new concentrated solutions gave results which met fully the requirements of the test. The same method of differentiation was employed. The color standards used for the original kit and the index system of classification employed therein continued as the medium by which new fixation data were classified and recorded.

As far as possible the test has been made a duplication of a field study in which the behavior of a soil in fixation is determined as a result of an application of soluble phosphate fertilizer. It is designed to give the field man usable information relevant to the question of what may be expected to occur in any given field were an application of phosphate to be made at the moment. In the use of the new concentrated fixation solutions (500 and 1000 parts per million of P_2O_5, respectively), and with the ratio of volume of solution to soil maintained at the original value (i. e., 30 cc. to 5 grams soil), the applications are equivalent to treatments of 7,500 and 15,000 pounds P_2O_5 per acre-foot of soil. In order to insure fullest fixation, the fixation solution is allowed to remain in contact with the soil for a longer period of time than was prescribed in the original ensemble. Solution and soil are shaken for three minutes at intervals of twenty-four hours, the total standing time being extended to forty-eight hours instead of the overnight period of about twelve to eighteen hours as was allowed in the first procedure when a more dilute solution was employed.

Method of Reporting Data:

The results obtained may be recorded by prefixing the serial number of the solution to the number of the color standard matched. The fixing solutions containing 100, 500 and 1000 parts per million phosphate have been designated, respectively, as solutions Series 100, 500 and 1000. Using the Series 100 solution, the index of fixation may be prefixed with "100," followed by the number of the color standard matched. For the Series 500 and 1000 solutions, prefixes of "500" and "1000" may be followed by a dash and the numbers of the color standards matching the color gradations developed in the test solution. The arrangement of data appearing in Table I may also be found convenient.

Using the modified kit containing the original solution (Series 100) plus the new, more concentrated fixation solutions (Series 500 and Series 1000) we present below a tabulation of data obtained in a typical soil comparison study. A scheme of recording results has been followed substantially equivalent to the one proposed above.

TABLE I.

FIXATION CAPACITIES OF SOIL MEASURED BY THE RAPID KIT METHOD OF ANALYSIS, USING SOLUTIONS SERIES 100, 500 AND 1000.

Lab. No.	Soil	Treatments equivalent to lbs. P_2O_5/acre-ft. 1500 — Fixation Indices — Series 100	7500 — Series 500	15,000 — Series 1000
9103	Waipio	40	0	0
9677	Hawaii	40	10	0
9676	Hawaii	40	20	0
8952	Kauai	50	40	0
8979	Kauai	60	20	0
8975	Kauai	70	10	0
9680	Hawaii	70	10	0
9326	Kauai	70	30	0
9678	Hawaii	80	10	0
9670	Hawaii	80	20	0
9329	Kauai	80	30	0
9633	Maui	80	30	0
9327	Kauai	80	40	0
9667	Hawaii	80	40	0
9674	Hawaii	90	20	0
9331	Kauai	90	30	0
9640	Maui	90	30	0
9332	Kauai	90	40	0
9328	Kauai	90	50	0
9334	Kauai	90	50	0
9639	Maui	90	60	0
8877	Hawaii	90	60	20
8882	Hawaii	90	60	40
8965	Kauai	90	70	10
9672	Hawaii	90	70	10
9662	Hawaii	90	70	20
8941	Kauai	90	70	20
9668	Hawaii	90	70	30
632	Hawaii	90	70	30
9641	Maui	90	80	10
9665	Hawaii	90	80	30
9664	Hawaii	90	80	40
9072	Hawaii	90	80	40
9663	Hawaii	90	80	50
8887	Hawaii	90	80	50
645	Hawaii	90	80	50
8880	Hawaii	90	80	60
9635	Maui	90	90	40
8871	Hawaii	90	90	50
9669	Hawaii	90	90	50
9671	Hawaii	90	90	50

Significance of New Fixation Kit Data:

Reference to Table I will show that differences in degrees of fixation are revealed when soils are treated separately with the concentrated fixation solutions (Series 500 and 1000) in addition to the old standard solution (Series 100). Thus, soils which absorb all the phosphate from the dilute solution and manifest apparently a similar degree of fixation, will, upon treatment with the more concentrated solutions, behave differently if variations in high fixation are inherent in them. Similarly, treatments of 15,000 pounds phosphate will reveal greater differences. To illustrate, referring first to the column of Series 100 indices in Table I and then to the other columns in the table, we note six soils showing indices of 80, which, however, manifest new indices of 10 to 40 on treatment with 7,500 pounds of phosphate. In the use of concentrated solutions where the blue test color produced in the solution after fixation is darker than the color standard "0," the index reported is still to be considered as "0" with the prefix of the series number of the solution used for the analysis.

Likewise, the observation regarding variations in fixation capacities is true for the entire list of soils bearing the index of 90 in column 1. By treatment with concentrated solutions an apparently high fixing soil can easily be differentiated as high, moderately high, or extremely high in fixation. Thus, taking soils Nos. 9674, 9672 and 645 from the island of Hawaii—these three soils possess apparently identical fixation of 90 in the Series 100 group, all showing high fixation. After treatment with the concentrated solutions magnifications of differences in fixation capacities in the soils are clearly shown. Thus, for the three soils we find:

Soil	Fixation Indices			Degree of Fixation
	Series 100	Series 500	Series 1000	
9674	90	20	0	High
9672	90	70	10	Moderately high
645	90	80	50	Extremely high

A Comparison of Rapid Kit Methods of Analysis With More Detailed Laboratory Procedures:

Many of the soils included in Table I have been extensively studied in the laboratory by Davis and Ayres with more refined methods of analysis. The method of Ayres (loc. cit.) involves continuous agitation of the soil for 24 hours with a solution of phosphate which has been adjusted to slightly below neutrality. Treatments correspond to applications of 25,000 pounds of P_2O_5 per acre-foot (2.5 million pounds) of soil. Following this procedure, 50 grams of soil are treated with 500 cc. of phosphate solution containing 1,000 parts per million P_2O_5. At the end of the maceration period, the liquid is filtered and the amount of phosphate remaining in the solution is determined by a volumetric procedure which involves precipitating the phosphate as ammonium phosphomolybdate and treating the washed precipitate with standard alkali and acid. Where only a small amount of phosphate is left unfixed, the filtrate is tested by a colorimetric method comparable to the one used in the rapid kit procedure. The results are reported in per cent of P_2O_5 fixed. A comparison of the results of the studies by Davis and Ayres with soils also

analyzed by the rapid kit method is submitted in Table II. The specimens were collected from points on the island of Hawaii. Their presentation in the table follows the order approximating a route around the island, starting from Hilo, progressing through Waiakea, the volcano area, Kau, Kona and Waimea to Kohala. On the return trip to Hilo the collection began again at Honokaa, and then continued along the coastline to Wainaku. Unless otherwise stated data presented were obtained from surface soils.

TABLE II.

TABLE COMPARING THE RESULTS OBTAINED BY A LABORATORY METHOD OF DETERMINING FIXATION WITH THOSE OBTAINED BY THE RAPID KIT METHOD. RESULTS BY THE LABORATORY METHOD ARE REPORTED IN TERMS OF PER CENT P_2O_5 FIXED AFTER APPLICATION OF 25,000 POUNDS P_2O_5/ACRE-FOOT. RESULTS BY THE FIXATION KIT TEST FOLLOW THE USUAL PRACTICE.

Lab. No.	Soil	*Detailed Lab. Det., 25,000 lbs. P_2O_5/ Acre-ft. Per cent Fixed	Rapid Kit Method Fixation Indices Series 100	Series 500	Series 1000
9682	Olaa Junction, Field, surface soil.........	99.0	90	80	30
9684	Road cut, 20 miles from Hilo, top soil....	99.1	90	80	30
9683	Road cut, 20 miles from Hilo, subsoil.....	99.8	90	90	50
9685	Leihua Forest, 25 miles from Hilo.......	69.7	80	30	0
9687	Sulfur mound near Volcano House.......	71.3	70	10	0
9686	Near edge of Halemaumau..............	2.2	0	0	0
9689	Near Thurston Lava Tubes.............	52.5	70	10	0
9675	Kipuka in Bird Park, forested knoll......	28.2	20	0	0
9678	Profile in Kipuka in Bird Park..........	56.6	80	10	0
9688	Kau Desert, near Punaluu..............	21.8	20	0	0
9681	Kau, near flow of 1868.................	66.7	60	10	0
9680	Kau, near flow of 1907.................	74.4	70	10	0
9674	Between Puuwaawaa and Humuula Junctions	79.5	90	20	0
9679	Kohala, near Iole......................	84.9	80	40	0
9670	Road cut near Niulii Mill, top soil.......	77.4	80	20	0
9672	Kohala to Waimea.....................	98.6	90	70	10
9673	Kohala to Waimea.....................	93.9	90	70	10
9669	Waimea to Honokaa....................	99.3	90	90	50
9671	Waimea to Honokaa....................	99.6	90	90	50
9856	Honokaa, mauka	99.2	90	60	20
9857	Honokaa, middle belt..................	98.8	90	50	0
9858	Paauhau	98.6	90	60	10
9867	Paauilo, No. 9, surface soil............	99.3	90	70	30
9868	Paauilo, No. 9, subsoil.................	99.9	90	90	40
9869	Paauilo, No. 9, makai..................	99.3	90	70	20
9870	Paauilo, No. 11........................	94.6	90	20	0
9871	Paauilo, No. 16........................	91.0	90	20	0
9872	Paauilo, No. 23........................	99.5	90	80	30
9873	Paauilo, No. 18........................	98.7	90	40	10
9874	Paauilo, No. 21........................	96.4	90	40	0
9859	Hamakua, Sample No. 5.................	98.8	90	40	0
9861	Kukaiau, No. 27, surface soil...........	99.2	90	70	30

* Data in this column were determined by either Davis or Ayres in other investigations.

TABLE II—(Continued).

Lab. No.	Soil	*Detailed Lab. Det., 25,000 lbs. P_2O_5/ Acre-ft. Per cent Fixed	Rapid Kit Method Fixation Indices Series 100	Series 500	Series 1000
9862	Kukaiau, No. 27, subsoil	99.9	90	90	70
9863	Kukaiau, No. 19	99.2	90	60	20
9864	Kukaiau, No. 8	98.8	90	60	10
9865	Kukaiau, No. 1, surface soil	95.9	90	30	0
9866	Kukaiau, No. 1, subsoil	99.7	90	90	30
9860	Kaiwiki	95.4	90	30	0
9662	Papaaloa	98.1	90	70	20
9663	Papaaloa	99.6	90	80	50
9664	Hakalau	98.8	90	80	40
9665	Honomu	98.7	90	80	30
9666	Pepeekeo	99.2	90	80	40
9667	Onomea	75.6	80	40	0
9877	Hilo, Lot 27	99.6	90	90	60
9878	Hilo, Lot 26, subsoil	99.9	90	90	80
9879	Hilo, Field 56	97.9	90	80	30
9876	Hilo Variety Station	98.9	90	80	40
9875	Hilo	98.5	90	80	40
9668	Hilo Substation, H.S.P.A.	98.6	90	70	30

* Data in this column were determined by either Davis or Ayres in other investigations.

Discussion of Data—New Fixation Assembly:

Inspection of Table II will reveal that for the initial test, i. e., Series 100 treatment, the lower ranges of fixation show a close correlation between the kit indices and the percentages of fixation as determined by a more elaborate method of analysis. From a study of the data obtained from the separate and additional treatment of soils with concentrated solutions (Series 500 and Series 1000), it becomes apparent that for soils analyzing 0 to 50 index values, the necessity does not exist for further differentiation with the concentrated solutions. However, when the Series 100 treatment shows an index value equal to or greater than 60, recourse to analysis by the concentrated solutions is desirable, with reanalysis absolutely necessary for values of 90 or greater if a finer classification of the degrees of high fixation is desired.

Rate of Fixation:

The indices obtained by the rapid method of analysis may not only be indicative of the fixation capacity of the soil, but in a measure may allow an estimation to be made of the rapidity with which applied phosphate may be fixed.

In the study of fixation by a conventional laboratory method, it has been shown that for some Hawaiian soils, fixation proceeds at a tremendous rate during the first hour and the amount fixed gradually increases until practically constant absorption is attained at the end of the first 5 to 10 hours. Fixation at this period, however, is by no means completed.

While no claim is made that the results obtained by the rapid kit method represent fixation at equilibrium conditions, the soil treatment containing the highest amount of phosphate must certainly have provided the soil with sufficient phosphate to satisfy, in a measurable degree, its propensity to fix this nutrient, and the time of contact is long enough so that the reading is made when fixation may have attained a limit wherein increase in amount absorbed becomes but negligible. It should follow then, we believe, that the rapidity with which soil removes phosphate from a fertilizer application may be estimated if the initial treatment, i. e., Series 100 analysis, is taken not only as a measure of the fixation capacity, but also as an indication of the progress of fixation during the period of high absorption. The more concentrated solution treatments, i. e., Series 500 and Series 1000 analyses, appear to indicate the progress of fixation during the period when the rate of fixation has dropped to lower values.

In the following table the soils are grouped and placed according to their fixation indices. The arrangement is in numerically increasing order, based on the Series 1000 treatment. For soils of moderate fixation, that is, those the capacity of which is represented by the index of zero after treatments of 15,000 pounds phosphate, column 2 will show capacity, and the rapidity of fixation may be judged from column 1.

TABLE III.

SHOWING THE FIXATION INDICES BASED ON THE NUMERICALLY INCREASING ORDER OF THE SERIES 1000 STANDARDS.

Lab. No.	Soil	Fixation Indices		
		Series 100	Series 500	Series 1000
9677	Hawaii	40	10	0
8975	Kauai	70	10	0
9678	Hawaii	80	10	0
9676	Hawaii	40	20	0
8979	Kauai	60	20	0
9670	Hawaii	80	20	0
9674	Hawaii	90	20	0
9326	Kauai	70	30	0
9329	Kauai	80	30	0
9331	Kauai	90	30	0
8952	Kauai	50	40	0
9327	Kauai	80	40	0
8965	Kauai	90	70	10
9641	Maui	90	80	10
9668	Hawaii	90	70	30
9665	Hawaii	90	80	30
9664	Hawaii	90	80	40
9635	Maui	90	90	40
9663	Hawaii	90	80	50
9669	Hawaii	90	90	50

In the first three soils, column 2, the same amount of phosphate is fixed in each within the longer period of treatment, whereas in the initial treatment with 1,500 pounds of phosphate for 24 hours, during a shorter period of maceration, indices of 40, 70 and 80 were obtained. It is indicated here that while the inherent capacity of phosphate fixed by these three soils may be identical within a longer period of contact, the amount taken up during the shorter period is variant. Hence, it may be concluded that the rate of fixation in these soils differs one from the other. The third soil of this group, Soil 9678, appears to fix the largest amount of phosphate within the shorter maceration period and hence the speed of fixation must have been the most rapid in this soil. It appears, then, that not only may the fixation capacity of a soil be indicated with the fixation kit but the rapidity with which fixation proceeds may also be estimated.

Detailed Procedure for Making Determination:

By following the procedure as outlined below, the agriculturist may determine with ease and rapidity, practical and accurate degrees of fixation in soils of low fixation and also in those where fixation is high and where the need exists for more exacting differentiation.

To determine capacity, rate and degree of fixation: Five grams of soil are measured in a calibrated metal cup and transferred to a 2-ounce graduated bottle previously filled to the 30 cc. mark with Series 100 fixation solution. The mixture is shaken for one minute and then allowed to stand for 24 hours. At the end of this period it is reshaken for another minute, then the liquid and soil are separated by filtration. The filtrate is collected in a 3-dram tall vial until it has been filled to about 2/3 of its capacity. One cc. of ammonium molybdate is added and the solution is thoroughly mixed. Then one drop stannous chloride reagent is introduced. A blue coloration will be produced in the test solution if phosphate remains in the filtrate. (When ammonium molybdate is added to a solution containing phosphate, ammonium phosphomolybdate is formed. This product is reduced by stannous chloride forming a blue colored solution.) This blue solution is matched against the standards already described and the results are tabulated in numerical indices. If the index obtained by this test is 60 or above, fresh portions of the soil may be retested, using the concentrated solutions.

Two 5-gram portions of soil are transferred separately to bottles containing 30 cc. each of the concentrated solutions, Series 500 in one case and Series 1000 in the other. Soils and solutions are shaken for three minutes, allowed to stand 24 hours, reshaken for three minutes, and finally allowed to stand for another 24 hours. At the end of this 48-hour period the mixture is shaken for another three minutes and filtered. The filtrate is treated in a manner similar to that for the Series 100 solution. The numerical indices are determined and tabulated with prefixes of the series numbers of the fixation solutions.

The ammonium molybdate solution is a 5 normal sulfuric acid solution containing 1.25 grams ammonium molybdate per 100 cc. In the preparation of stannous chloride solution 25 grams $SnCl_2.2H_2O$ are dissolved in one liter of 10 per cent hydrochloric acid solution.

A Means of Soil Classification:

The rapidity and ease with which soil fixation constants may be determined with the rapid methods and the distinctively individual characteristic nature of such data renders the process an ideal one as a means of soil classification.

CONCLUSION

A rapid method of determining fixation of applied phosphate in a soil is described wherein agitation of the soil specimen with neutral solutions of phosphate of definite variable concentrations are employed. Data relevant to fixation are ascertained by determining the quantity of phosphate remaining in the added solution as it may stand, after a given period of time, in a clear supernatent fraction above the soil sample. Rate, capacity and degree of fixation are then estimated and expressed in numerical indices. The method appears to offer a means of correlating soil fertility with soil phosphate fixation and in addition it offers an excellent means of making a general soil classification.

Low to moderate fixation in a soil may be determined by the ensemble using solutions containing 100 parts per million of phosphate from diammonium phosphate.

In cases of moderate to high fixations additional relevant data may be obtained by further analyses of fresh portions of the soil with more concentrated solutions of the same fertilizer compound.

Where differences in extremely high fixation are to be differentiated it is necessary to use concentrated fixation solutions, the treatments of which are equivalent to fertilizer applications of 7,500 and 15,000 pounds of P_2O_5 per acre-foot, respectively.

Data accruing from these tests may be correlated quite satisfactorily with those determined by more detailed laboratory methods.

SUMMARY

Discussion is presented relevant to the development of the Experiment Station Rapid Method of Evaluating Soil Phosphate Fixation. Principles pertaining to the manner of procedure are set forth.

A detailed description is presented of the present (new) phosphate fixation ensemble—a list of reagents, apparatus and other equipment which may be used to evaluate soils in their reaction toward absorption of applied phosphate fertilizer. Differentiation of capacity, rate and degree of fixation may be estimated from the data secured. Examples are given of the application of the method to agricultural problems.

LITERATURE CITED

(1) Ayres, A. 1934. Phosphate fixation in Hawaiian soils—II. The Hawaiian Planters' Record, Vol. XXXVIII, pp. 131–145.

(2) Davis, L. E. 1934. Phosphate fixation in Hawaiian soils—III. The Hawaiian Planters' Record, Vol. XXXVIII, pp. 206–215.

(3) Demolon, A. and Barbier, G. 1930. Sur l'appreciation du besoin des sols en acide phosphorique. Comptes Rendus, 190, pp. 765–767.

(4) Hance, F. E. 1933. Phosphate fixation in Hawaiian soils—I. The Hawaiian Planters' Record, Vol. XXXVII, pp. 182–196.

A Procedure for Sampling Cane Juice and Soil as Used at Pioneer Mill Company, Ltd.*

By H. J. W. Taylor

Since the year 1922, several surveys of Pioneer Mill Company's soils have been made. Using the 1 per cent citric acid soluble method of analysis, it was impracticable to take more than two or three soil samples to represent a single field, and for the majority of fields but one sample was taken. This sample may have been a composite of many borings taken throughout the field, or a sample from a smaller area taken as representative of that field. When the sampling was repeated in later years, it was not definitely done in the same manner or in the same soil area or at the same stage of the cane's growth. However, it has been possible to obtain some general correlations between these soil analyses and other experimental and analytical data accumulated from the larger areas, i. e., the "mauka," the "outside," or the "pump water" areas, etc. Far more detailed information is necessary to bring these correlations to a finer point in order to formulate a differential fertilizer practice for individual fields, or parts of fields. In this regard, the recent development of the rapid kit methods of soil analysis, and the rapidity and cheapness of operating these kits presented themselves as a means of obtaining this information.

Mr. J. T. Moir first suggested to us that advantage be taken of these soil kits by sampling the soil from each "burn" at time of harvest, at the same time loading on separate cars the cane grown on that specific soil area sampled, and thereafter obtaining the potash and phosphoric acid contents of its crusher juice. Further discussion with members of the Experiment Station staff and others resulted in a method of soil sampling being developed whereby an area of approximately 0.3 to 0.5 acre is taken to represent the surrounding 5.0 acres, and data on the following subjects accumulated from these sampling stations:

(a) Kit Analysis—K_2O and P_2O_5; also pH
(b) Juice Analysis—K_2O and P_2O_5
(c) Cane Yield
(d) Brix, Pol and Purity

Cutting:

At the outset of this routine, an attempt was made to separate the boundaries of the area to be sampled by selecting the site after burning and staking it before the cutting gang commenced. In order to take a running crusher juice sample of all the cars loaded from this area, without the necessity of switching cars in the mill yard, it was necessary to select watercourses from which the cane could be loaded upon cars in an unbroken string. In many cases, however, the track lines ran in such a

* **Presented at a meeting of the Maui section of the Association of Hawaiian Sugar Technologists, Agricultural Division, Lahaina, Maui, March 14, 1935.**

manner that it was not possible to load all the sample cane on the same line, and it was equally difficult to estimate where the track lines would run in subsequent areas in order to correct this. Sample plots are therefore selected and flagged out after the cane has been cut, and after the track line has been installed.

In order to reduce the error of mixed cane as much as possible when selecting the sample area at this stage, all cane irrespective of location is separated at the level ditches at cutting. It has been found possible to do this without slowing the cutter to any extent, and the fact that no cane is laying in the level ditch is some help to the loader.

The error due to mixed cane is thus confined to the two outside watercourses of the four or five that are selected for each sampling station. Observations made by numerous persons at the harvesting of these areas have not found this error to be a large one.

Loading:

The ticket boy, in cooperation with the harvesting luna, is responsible for supervising the loading of the sample cane. This is not difficult, as the four yellow flags marking the corners of the sampling station are visible from a fair distance, and he can see any man loading cane inside or outside of these points without standing directly over the men all the time. The loaders themselves soon become proficient in recognizing the yellow flags as marking areas that are to be loaded separately from the adjacent cane.

Sample-cane tickets of a different color than the experiment- or crop-cane tickets are placed in the car, and as there are never, or very rarely, two cane samples taken from the same level ditch, the level ditch number marked on the ticket serves to record the location of each cane sample. The cars are also marked with the same number so that the tractor driver or locomotive engineer observing the chalk marks may exercise care in seeing that the string of cars gets to the mill yard without being separated. After the cane has passed through the mill, one of the roundhouse hands removes old chalk marks to avoid confusion later.

Flume Fields:

The method of cutting cane in flume fields is exactly the same as in track fields except that the sample station instead of being four or five watercourses on a single level ditch, is three watercourses each on two level ditches, the flume running directly through the middle and the cane being loaded from 1½ watercourses on either side of the flume. Due to the larger percentage of outside watercourses in these sample stations, the error of mixing at cutting is no doubt larger.

The chance for error in loading cane from flume fields is considerably greater also, due to the difficulty in supervision at the chute. The method of fluming is exactly the same as that used in field experiments, i. e., a break is made in the fluming operation, allowing all crop cane to get several hundred feet down the flume on its way to the chute, and then a bundle of cane tops with a split section of cane stalk containing a note with the number of the plot is placed in the flume by the gang luna. Sufficient time is given the chute men, after receiving the note and plot number to take out the partially loaded car and place an empty one in the chute before fluming

is again started. The procedure is duplicated at the conclusion of fluming the cane from each plot.

In fluming these sample areas, it is not practical to have a special attendant at each chute to insure new cars being put in at the proper time, so confidence has to be placed in the gang which is handling the chute. They may be checked upon to a certain extent by noting how many partially loaded cars there are, for it is impossible that fluming would commence from every sampling area just as an empty car had been placed under the chute, or concluded just at the moment a car had been filled.

Flume cane cars are marked in the same manner as track cars.

Juice Sampling:

At the present time, juice sampling is handled entirely by the mill laboratory men in the same manner as field experiments. The number of cars representing a sample is usually from 8 to 10, so that a good running crusher juice sample is obtained. There are usually six samples taken each day, and it requires one man two hours in the morning to make the potash and phosphoric acid analyses for these samples. He records his results on a separate sheet for each field, and when the field is finished, gives his record to the field experiment department, to be entered with the other data in their record book.

Soil Sampling:

Soil samples are taken from each sampling station immediately after loading is concluded. These are not taken with an auger, but a garden trowel or small hand pick is used. The top four or five inches of soil are scraped away from the mauka lower portion of the bank, and about two handfuls of soil are dug out and placed in a bucket. This is repeated in every fifth line approximately 10 feet in from the watercourse, in each watercourse of the selected sample area. Altogether about 20 to 25 of these unit samples are placed in the bucket and are then thoroughly mixed together, then about 1½ pounds of this mixed soil is placed in a paper bag upon which the soil number is written. This sample is the one that is used for analysis.

The soil number is entered in the sampler's book with the sampling date, and information such as field slope, rockiness, physical soil condition, proximity to straight ditches, etc., is added. The level ditch number, and the number of watercourses to the road or straight ditch or fire road are also noted, so that the exact sample spot, 10 feet from the watercourse on every fifth line, may be easily relocated.

The soil is obtained from the lower portion of the mauka bank in order to avoid undue influence of a previous application of fertilizer that may have been made on the cane row. The analysis of such a soil sample should indicate the more natural fertility of the area.

Surveying:

In order to obtain accurate areas of each sample station, to work up its cane and sugar yield, it is surveyed by our civil engineering department. The flags marking the boundaries are left in the field until after surveying, so that at the conclusion of

harvest in each field the surveyors may go in and survey all the sample areas at one time. Sufficient information is taken at that time so that the exact location of each sampling station may be traced on the field map. This will be an additional aid in relocating the stations from year to year, as we shall have to do in order to watch the fertility trends that may result from a differential fertilizer practice which may be adopted.

Accumulation of Data:

At the conclusion of each analysis and after the cane and sugar yields have been computed, the data are entered in our record book as follows:

Field.................... Variety.................... Section.................... Elevation.................... Crop....................

Sample Date	Soil No.	Area Acres	Level Ditch No.	SOIL ANALYSES					JUICE ANALYSES						Tons Cane Per Acre
				pH	Potash			Phosphate Group	K_2O Per Cent	P_2O_5 Per Cent	Brix	Pol	Pur.	Q.R.	
					Per Cent	P.P.A.F.	Group								

The K_2O and P_2O_5 groups as found are located on individual field maps by means of colors (yellow, blue, green and red) representing, respectively, a High, Medium, Doubtful and Low supply. In this way it is possible to note definite trends within the fields. (Frequently the increased P_2O_5 and K_2O concentration in areas which have received filter cake or molasses may be clearly seen by a glance at these maps.)

In some cases it has already been possible to correlate the T.C.P.A. with the P_2O_5 or K_2O content, and it is evident that many interesting and valuable data will be available at the conclusion of this work. At present, some 374 sample stations have been studied for K_2O and P_2O_5 in both soil and juice since the commencement of harvesting the 1935 crop, and at the close of the year we expect that approximately 1,061 such sample stations will have been analyzed, covering 5,307 acres of the plantation. From these it is hoped that much definite information regarding miscellaneous correlations will be available, and that when specific evidences of our soil fertility differences are found, they will be of much practical use to the plantation.

A Fertilizer Policy Developed With the Aid of Experiments*

By W. W. G. Moir

At the request of the agricultural section of the Maui sugar technologists the writer has attempted to prepare, in the rather short period of time since receiving the request, a paper on just how the fertilizer policies of Pioneer Mill Company, Ltd., have been evolved through experimentation. This plantation has harvested hundreds of tests on various points connected with fertilization alone, and most of these have been studied and summarized in the tables attached to this article. The details of the treatments and the comments on each and every experiment would be of much interest to everyone but would take too much space and time in presentation here. The writer will therefore take you through the years of work from 1919 to the present time showing how the practices have changed—mostly through results of well-replicated tests. Many of the points and methods of investigation were changed and elaborated upon as the work progressed. Results of experiments on other plantations and ideas obtained in scientific articles of all kinds were used to aid in this work and to arrive at a saner fertilization of the soils at Pioneer. The writer has been connected with this work from the start, and in the last ten years in an advisory capacity in connection with his work as Agricultural Technologist for American Factors, Limited, agents for Pioneer Mill Company. Approximately half of the experiments have been carried out under the supervision of the Experiment Station, and their aid and cooperation have been most invaluable.

A short discussion of soil differences must be given to start with. Roughly, the lands of Pioneer Mill Company can be divided into three general groups or types of soils. First, there are the red and reddish-brown soils that are rather free of rocks and have been formed by weathering in their present place. Second, there are the rocky soils made up of at least two-thirds boulders of all sizes and shapes from pebbles to those the size of a small automobile Third, there are the alluvial flats of silt, sand and gravel deposits brought down by the streams and run off from the higher elevations. The first group is found in upper Lahaina, Wahikuli, Puukoli and Honokawai sections (the lower fields of the latter two as well). The second group is found in lower Wahikuli, Lahaina and upper Olowalu sections, while the third is to be found on the flats of Puukoli, Lahaina and Olowalu. In general, the areas of the first group are deficient in phosphates to a marked degree and in potash to a more or less degree. The second group will respond to phosphates and potash to a smaller degree, while the third group seldom responds to anything but nitrogen. Naturally, any general resumé of conditions along these lines will not cover individual fields in some of these groups, but in a very general way this classification will hold. The border fields between these groupings will naturally be found partly in one and partly in the other.

---

* A paper presented at a meeting of the Maui section of the Association of Hawaiian Sugar Technologists, Agricultural Division, Lahaina, Maui, March 14, 1935.

TABLE I

AVERAGE FERTILIZATION AT PIONEER*

Crop Year	1st Season N	1st Season P_2O_5	1st Season K_2O	2nd Season N	Total N	Total P_2O_5	Total K_2O	Amount and Material
1924	75	52	38	97 (1)	172.5	52	38	750 lbs. (10–7–3.75) + 625 N.S.
1925	75	52	38	97 (1)	172.5	52	38	750 lbs. (10–7–3.75) + 625 N.S.
1926	87½	87½	0	87½ (1)	175	87½	0	437½ lbs. S.A. + 437½ super + 567½ N.S.
1927	90	90	60	97 (1)	187	90	60	1000 lbs. HG (9–9–6) + 625 N.S.
1928	140	190	125	75–100(1)	215–240	190	125	625–687½ lbs. (15–10) 1000 (9–9–6) 250 S.A. + 500–750 lbs. N.S.
1929	140	236	158	87–116(2)	227–256	236	158	1750 lbs. (PMS) (2¾–13.5–9) + 437½ S.A. + 562½–750 N.S.
1930	140	236	158	97–116(2)	237–256	236	158	1750 lbs. (PMS) (2¾–13.5–9) + 437½ S.A. + 625–750 N.S.
1931	152	220	121	77–102(2)	229–254	220	121	1125 lbs. A6 (4¼–19½–10¾) + 875–1000 S. A.
1932	152	220	121	77–102(2)	229–254	220	121	1125 lbs. A6 (4¼–19½–10¾) + 875–1000 S. A.
1933	152	220	121	102(2)	254	220	121	1125 lbs. A6A (muriate mixture) + 1000 S.A.
1934	145	208	110	102(2)	247	208	110	500 lbs. A17 (9½–41½) + 250 N.K.G. + 812½ S.A.
1935	154	220	120	104(2)	258	220	120	750 lbs. A19 (6.7–29¼–16) + 1000 S.A.

* These figures are not uniform for the whole plantation but are somewhat representative of the larger share of lands in each crop year.
(1), (2)—one dose and two doses.

In Table I you will find a broad generalization of fertilizer practices followed on the plantation in the years from 1924 to the present time. Changes in plant food applications can be readily seen and will be commented upon as the article progresses.

Three general soil surveys conducted by the Experiment Station in 1922, 1926 and 1927, as well as individual analyses of experimental soils, gave the first real basis upon which to proceed.

The first survey showed in a very general way the areas very low and deficient in plant foods, and they have remained that way through later surveys, although in some areas there was an improvement from the use of phosphates and potash where the deficiency was not too great. Individual samples during the last few years show much greater improvements in these plant foods through fertilization. Experimental data show distinct gains in fertility or availability of potash and phosphate through continued heavy applications. These gains have been shown in crusher juice analyses as well as in the soil analyses.

TABLE Ia

AVERAGE OF 1 PER CENT CITRIC ACID SOIL ANALYSES—PIONEER MILL CO.

1922-32

Field Groups	No. of Analyses	pH	SiO_2	CaO	K_2O	P_2O_5	Section
30-34	(16)	6.4	.12	.16	.046	.0035	(Honokawai)
A	(4)	6.6	.10	.16	.037	.0032	(Puukoli)
B	(12)	6.5	.13	.18	.048	.0065	
C	(13)	7.2	.17	.18	.040	.0054	
D	(8)	7.9	.21	.42	.067	.0289	
E	(4)	6.3	.11	.14	.030	.0030	(Wahikuli)
F	(7)	6.2	.09	.13	.032	.0056	
G	(4)	6.1	.09	.10	.021	.0071	
H	(8)	7.0	.18	.19	.039	.0082	
I	(6)	7.2	.18	.22	.043	.0129	
LA	(18)	6.8	.14	.18	.033	.0039	(Lahaina "L")
LB	(13)	7.0	.17	.20	.030	.0060	
LC	(17)	7.8	.25	.32	.038	.0164	
LD	(3)	8.1	.26	.38	.051	.0283	
O	(16)	8.0	.27	.42	.059	.0603	
MA	(7)	6.9	.20	.28	.075	.0118	(Lahaina "M")
MB	(10)	7.3	.21	.26	.057	.0123	
MC	(7)	8.0	.26	.41	.041	.0132	
MD	(17)	7.8	.22	.46	.051	.0631	
Olowalu	(51)	7.6	.27	.54	.036	.0688	(Olowalu)

Total of 241 soil analyses.

In Table Ia are given the average figures for one per cent citric acid analyses from the years 1922 to 1932. Most of these are in 1922, 1926 and 1927. The figures are divided into groups of fields, that is, all the "A's," all the "B's," all the "C's," etc. They are again grouped into sections—Honokawai, Puukoli, Wahikuli, Lahaina and Olowalu. In each grouping by section, the higher elevation fields are given first and these are followed in turn by groups at lower and lower elevations. In the Honokawai section no distinction is made between pump and mountain water areas. In the Puukoli section up until very recently the "A" and "B" fields have had only mountain water, while the "C" and "D" have had mostly pump water. In the Wahikuli section the "E," "F" and 'G" fields have had only mountain water, while the "H" and "I" have had mostly pump water. In the Lahaina section the "LA" and "MA" fields have had mountain water only, while the others have had mostly pump water. Olowalu has had a mixture of both types of water except in a few cases and these have not been separated out in the averages. Please note in Table Ia the increase in available plant foods and pH as one comes from the higher elevations of 1,500 and 800 feet down to the areas at sea level. Also note the increase in these figures as one moves from Honokawai into Lahaina and Olowalu.

Crusher juice analyses for phosphate and potash have been made since 1922 with an occasional year left out. These figures on the whole check very nicely with the soil survey figures in showing the fields that are low and those that are high in the availability of these plant foods. There has been a slight improvement in the phosphates in the juice of the later harvestings compared with those before the heavy phosphate fertilization started. In some of the experiments of the N, NP, NK, NPK type, increases of about a hundred per cent have been noted in the juices from plots receiving phosphate over those not receiving this plant food. On the whole, it is much more difficult to show increases of phosphate in the juice of cane from phosphate fertilization than it is to show increased potash in juice from potash fertilization. This undoubtedly is due to the differences in amount of these two elements in the juices. The potash ranges from five to fifteen times the amount of phosphate in cane juices at Pioneer Mill Company. On other plantations this may range from one to twenty in mature cane.

TABLE Ib

AVERAGE OF CRUSHER JUICE ANALYSES (PER CENT BRIX) FOR FIELDS OF PIONEER MILL CO.

1922-1935

Field Groups	1922-1927 P_2O_5	1922-1927 K_2O	1928-1935 P_2O_5	1928-1935 K_2O	1922-1935 P_2O_5	1922-1935 K_2O
30-34	.068 (18)	1.150 (16)	.076 (8)	.747 (6)	.071 (26)	1.040 (22)
A	.053 (14)	.564 (11)	.071 (5)	.514 (5)	.058 (19)	.548 (16)
B	.071 (25)	.660 (23)	.103 (22)	.603 (16)	.086 (47)	.637 (39)
C	.110 (25)	1.857 (24)	.281 (21)	1.645 (16)	.188 (46)	1.772 (40)
D	.230 (35)	1.783 (34)	.281 (14)	1.672 (10)	.244 (49)	1.760 (44)
E	.056 (11)	.632 (10)	.069 (5)	.381 (5)	.060 (16)	.548 (15)
F	.056 (16)	.588 (15)	.083 (16)	.371 (13)	.070 (32)	.487 (28)
G	.065 (14)	.503 (13)	.076 (15)	.484 (11)	.071 (29)	.494 (24)
H	.100 (24)	1.470 (23)	.143 (23)	1.102 (15)	.121 (47)	1.325 (38)
I	.179 (18)	1.865 (15)	.177 (18)	1.093 (12)	.178 (36)	1.521 (27)
K	.100 (4)	1.019 (4)	.124 (6)	.916 (5)	.115 (10)	.961 (9)
LA	.073 (18)	.535 (18)	.103 (20)	.334 (16)	.089 (38)	.460 (34)
LB + Sch.	.100 (31)	.899 (29)	.124 (29)	.715 (20)	.113 (60)	.824 (49)
LC	.179 (22)	1.398 (22)	.173 (20)	1.447 (15)	.176 (42)	1.418 (37)
LD	.205 (15)	1.590 (15)	.195 (12)	1.433 (9)	.200 (27)	1.530 (24)
O	.236 (46)	1.843 (44)	.273 (31)	1.511 (26)	.251 (77)	1.720 (70)
MA	.082 (11)	.659 (10)	.107 (13)	.769 (9)	.096 (24)	.716 (19)
MB	.106 (17)	.930 (17)	.106 (15)	1.248 (9)	.106 (32)	1.040 (26)
MC	.155 (22)	1.515 (20)	.143 (22)	1.365 (20)	.149 (44)	1.440 (40)
MD	.252 (32)	1.739 (25)	.229 (21)	1.690 (18)	.240 (53)	1.689 (43)
Olowalu			.213 (54)	.824 (55)		

Each figure in parenthesis represents the number of times the fields in each group have been harvested.

Each figure not in parenthesis represents averages of averages secured from several samples in each field.

In Table Ib will be found the averages of crusher juice analyses per cent Brix for the fields of Pioneer during the years 1922 to 1935. These are grouped in the same way as in Table Ia for soil figures. These figures represent averages of 808 field harvestings for phosphate and 699 for potash. Each of these field harvestings represents an average of several analyses made while the field was in process of being harvested, so thousands of analyses make up these summaries. The period from 1922 to 1927 is given separately from that of 1928 to 1935, because the big increase in nitrogen and phosphate and the medium increase in potash fertilization for the plantation practice took place in the 1928 crop, as is shown in Table I. Please note the close similarity in the changes in these figures to the changes in the soil figures mentioned above. The second period (1928-1935) shows, in general, higher

phosphate figures and lower potash figures than the early analyses. The reverse should have been the natural expectation because of the change from crops averaging above 23 months of age to those of today averaging just below 20 months.

A study of these figures in greater detail shows that the larger increases in phosphate in the juice are from the areas getting the increased phosphate fertilization. These figures, together with other data, show that the plantation is undoubtedly getting much value from the increased phosphate fertilization. The steady decrease in potash throughout this period is somewhat alarming but only so in the mountain-water areas where the figures are low. These crusher juice figures, together with the low soil figures and the experimental data showing response to potash in these same areas, make it quite necessary to increase potash applications to these fields. This is spoken of again later under the experiments on potash.

A very striking set of figures can be shown by dividing the fields in the LB group that received mostly mountain water since 1931 or thereabouts, and those that received mostly pump water. All these fields previous to that time had pump and mountain water almost equally distributed.

	P_2O_5 Per Cent Brix	K_2O Per Cent Brix
LB fields—mountain water	.115	.574
LB fields—pump water	.137	.977

Compare these with the previous period and you will easily see how quickly the potash in crusher juice figures drops when pump water is no longer applied.

During the years 1924 and 1925 a fertilizer practice using only straight materials was followed, and no potash was applied except through the use of molasses in a very few areas and the application of pump waters high in potash. Undoubtedly this potash in pump water must be of value as a fertilizer, for a comparison of the crusher juice potash analyses of the cane from fields receiving pump water and those just across the pump ditch receiving mountain water shows a very much higher figure for the pump water treatment.

The early tests harvested soon showed the plantation authorities that increased amounts of phosphates and nitrogen were very necessary, and that potash was needed to a somewhat lesser degree, but was still quite necessary. On the strength of this a change to the use of mixed fertilizers was made, first using the Oahu formula 9-9-6 and then mixtures made up for their own conditions. The various changes in the practices given in Table I have been brought about through the results of the experiments harvested, and these will be discussed under separate headings of amounts, time of application and forms of the various plant foods. However, before embarking on this discussion, a few points should be brought out in regard to experiments of the type carried out at Pioneer. The maximum and minimum treatments have invariably been next to each other in the field. Those of you who are at all familiar with border effect of fertilizer experiments must therefore realize that the minimum treatment benefits at the expense of the maximum. The greater the difference in growth from the fertilizer treatments, the greater becomes this robbing of one to help the other. Therefore, the minimum treatment is not a true representation of what the plantation field would be like if handled by the minimum treatment, nor would the maximum one be either. It becomes necessary, therefore, to use all

experimental data as indication of a trend in one way or the other and not as the result of a certain treatment. Maybe the oft-heard expression "depressed yields from higher applications" can be partly explained in this way. Details of time of application obtained in some experiments cannot always be incorporated in all experiments, so a great deal of good common sense is required in utilizing all the data available in arriving at a sane fertilizer policy, even when some experimental results point against them.

It would be a bit less confusing to discuss the experiments in their order but it would require much more time and space than the writer has available. He will therefore group these tests into those of the various plant foods. Each of these groupings cover several years of harvesting and in each the amounts of plant food were changed, both as to the variable and as to the supplementary doses of other elements, but the general averages and listings show exceedingly strong trends that can be utilized with a great deal of reliability. A study of the details of these tests would be well worth while.

Nitrogen

The tons-sugar-per-acre yield from amounts-of-nitrogen tests over the whole plantation and throughout the years from 1921 to 1934 are listed in Table II. These 89 harvestings show that the optimum application is somewhere between 200 and 300 pounds of nitrogen per acre. In a study of the tests having larger supplementary doses of plant foods, those having the larger share of the nitrogen in the first season and those having the second-season application split into two, it becomes apparent that the greatest economical response is closer to the higher figure given above, that is, 300, than it is to the lower. In utilizing this figure in a plantation schedule, the other factors of location, time of year, length of crop, water supply and variety must enter the problem.

There has been an almost consistent increase in quality ratio with increased amounts of nitrogen throughout all these tests. Even with this change in quality there has nearly always been sufficient increased sugar production to take care of the poorer juices and still give an added profit.

In the tests of the 1927 crop and those prior to that year, the amounts-of-nitrogen experiments had the variables in the second season while in later years the variables were in the "boom stage" period of the first season. As pointed out above, the maximum yields seldom exceeded the 200-pounds-per-acre application in the earlier harvests. Later with the first-season variables the maximum yields often exceeded the 250-pounds-per-acre point. The first-season fertilization in the older tests was limited to 100 pounds of nitrogen regardless of time of starting but this was later raised to 140 pounds per acre. In the earlier tests the nitrogen was often applied in one dose each season. It can be seen from our present-day knowledge that this would hardly give the best yields.

At first only a few number-of-application tests were started, and they strongly indicated better yields from more than one application each season. Later, with the larger amounts of plant foods used, these results became even truer. In Table III will be found the sugar-per-acre yields of one versus two applications of the same amount of nitrogen in the second season. The average of these twenty-six comparisons gives 10.11 tons of sugar per acre for one dose against 10.55 tons of sugar

TABLE II

TONS OF SUGAR PER ACRE IN NITROGEN EXPERIMENTS AT PIONEER

Expt. and Field	Year	Plant Food P_2O_5	K_2O	Pounds per Acre 100	150	200	250	300	350
2 (B6)	1921	varied		6.58	7.37	7.22	7.30		
	1923	varied		5.71	6.88	7.30	7.65		
	1925	90	0	5.94	6.39	7.19	7.16		
14 (B4)	1925	100	0	13.38	13.81	14.19	14.36		
	1927	150	100		9.21	9.29	9.87	10.18	
	1929	300	250		7.33	8.77	8.81	9.16	
	1930	250	200		6.40	6.73	6.93	7.02	
16 (32)	1925	100	0	10.75	10.70	11.17	10.98		
	1927	150	100		8.03	8.37	8.51	8.51	
	1929	300	250		7.72	8.62	9.07	8.48	
	1931	250	200		9.18	9.65	10.03	9.59	
19 (LA7)	1925	100	0	12.91	13.51	13.90	15.41		
	1927	150	100		11.84	11.96	12.07	11.56	
	1928	300	250		7.15	7.50	7.75	7.80	
	1930	300	250		9.34	9.36	9.85	10.96	
	1931	300	200			8.52 8.61	8.70	10.08	
23 (G2)	1925	100	50		10.15	10.58	11.28	11.23	
	1927	150	100		7.94	8.99	9.29	9.62	
	1928	300	250		7.32	9.42	9.15	8.38	
	1930	300	250			9.51	10.59	9.86	11.53
	1932	300	250			11.37	11.50	11.64	11.53
25 (08)	1925	100	0	9.59	9.96	10.65	9.82		
	1926	100	50	7.14	7.33	7.57	7.22		
	1928	150	100		8.97	9.13	9.22	8.83	
30 (A5)	1926	100	50		6.32	6.07	6.36	6.91	
	1928	200	150	5.82	7.27	6.46	6.53		
32 (B1)	1926	100	50		13.30	13.80	13.90	14.49	
	1928	200	150			10.22	9.96	11.03	10.96
	1930	300	250			9.09	8.91	8.95	9.75
	1932	300	250			7.38	8.23	9.11	8.92
34 (30)	1926	100	50		10.67	11.25	11.50	11.32	
	1928	200	150		10.43	10.63	10.50	10.54	
	1930	300	250		10.83	12.08	11.73	11.98	
	1932	300	250		11.29	11.94	12.53	11.63	
36 (C3)	1926	100	50	10.43	9.60	10.38	10.93		
	1928	150	100		10.44	11.10	10.81	11.38	
	1930	300	250			9.22	9.38	9.03	9.39
	1931	300	250			7.22	7.66	7.85	7.48
49 (E2)	1927	150	100		9.49	9.66	9.70	10.22	
	1929	300	250		11.86	12.05	12.91	13.44	
	1931	250	200		10.37	11.34	11.87	12.51	
62 (MA6)	1927	150	100		11.58	13.26	12.23	12.01	
	1929	300	250		8.75	8.91	10.92	10.11	
	1931	250	200			8.46	10.30	10.53	
67 (B3)	1928	200	150			14.43	14.35	13.90	13.36
	1930	210	143			11.52	12.17	12.32	12.11

TABLE II—(Continued)

TONS OF SUGAR PER ACRE IN NITROGEN EXPERIMENTS AT PIONEER

Expt. and Field	Year	Plant Food P_2O_5	Plant Food K_2O	Pounds per Acre 100	150	200	250	300	350
89 (B6)	1932	300	250			13.92	**13.99**	13.29	13.21
	1934	300	250			11.95	12.18	11.71	**12.21**
93 (34)	1933	250	200		10.44	10.90	**11.24**	11.24	
101 (E1)	1933	250	200			**11.54**	11.40	11.34	11.54
105 (20)	1933	150	150		10.58	**10.93**	10.81		
	1934	100	200		8.21	**8.55**	8.30		
109 (5)	1933	150	150		**6.62**	6.58	6.11		
215 (32A)	1929	240	160			9.56	9.74	**10.26**	
217 (A3)	1929	240	160			7.14	**7.63**		
218 (B6)	1929	240	160			**14.08**	13.74	13.65	
223 (C6)	1929	236	157				10.72	**11.72**	11.54
	1931	236	157				11.06	**11.24**	10.34
227 (LA3)	1929	240	160				**10.84**	10.39	
217 (A3)	1927	90	60		6.32	**6.59**			
223 (C6)	1927	90	60		9.33		**9.99**	9.51	
Fd. 32	1927	90	60		6.90		**7.32**		
Fd. MC2	1928	90	60				10.85	**12.23**	
Fd. F5	1928	158	105				9.45	**10.05**	
LA2	1927	90	60			13.76	12.94	**14.00**	
LA5	1927	90	60			9.74	9.71	**9.77**	
248 (41)	1927	90	60			**12.75**	12.33		
LB4B	1927	0	0			6.46	**6.61**		
LB6	1927	0	0			**8.31**	7.96		
LC5	1927	0	0			**9.13**	9.08		
MD2	1927	0	0			6.94	**7.93**		
214 (33)	1929	236	157			**9.37**	8.80		
214 (33)	1929	236	157			**9.74**	9.28		
214 (33)	1931	236	157				**10.46**	9.89	
214 (33)	1931	236	157				**10.66**	9.27	
219 (B7)	1929	236	157			**11.80**	11.45		
	1929	236	157			12.41	**12.76**		
	1931	236	157				11.33	**11.83**	
	1931	236	157				**12.83**	12.72	
225 (F2)	1929	240	160			10.42	**11.35**		
	1929	240	160			11.30	**11.48**		
228 (LA4)	1929	240	160			**12.69**	12.23		
	1929	240	160			12.16	**12.54**		
	1930	240	160			**9.63**	9.42		
	1930	240	160			9.27	**10.11**		
231 (07)	1929	90	60			**10.28**	10.24		
	1929	90	60			**11.17**	10.98		
	1931	90	60			**11.25**	10.00		
	1931	90	60			**11.48**	11.01		

Total number of harvestings—89.

Total high yielders in each treatment................ 3 26 29 26

Bold faced figures represent the highest yielder in each experiment.

TABLE III

TONS OF SUGAR PER ACRE COMPARING ONE WITH TWO APPLICATIONS IN THE SECOND SEASON AT PIONEER

Expt. and Field	Crop Year	N	P_2O_5	K_2O	One	Two
5 (B6)	1921	200	70	37.5	6.84	6.86
	1923	200	70	37.5	7.79	8.16
	1925	200	92		7.41	7.81
LB4a	1927	228			9.23	8.95
LLSL	1927	264	90	60	10.90	11.50
MC6	1927	264	90	60	8.85	9.17
260 (F3)	1930	250	236	157	8.93	10.13
261 (LB2)	1930	250	236	157	10.36	10.64
214 (33)	1929	225	236	157	9.37	9.74
	1929	265	236	157	8.80	9.28
	1931	253	219	120	10.46	10.66
	1931	303	219	120	9.89	9.27
219 (B7)	1929	227	236	157	11.80	12.41
	1929	267	236	157	11.45	12.76
	1931	253	236	157	11.33	12.83
	1931	303	236	157	11.83	12.72
225 (F2)	1929	227	240	160	10.42	11.30
	1929	267	240	160	11.35	11.48
228 (LA4)	1929	227	240	160	12.69	12.16
	1929	267	240	160	12.23	12.54
	1930	227	240	160	9.63	9.27
	1930	267	240	160	9.42	10.11
231 (O7)	1929	227	90	60	10.28	11.17
	1929	267	90	60	10.24	10.98
	1931	215	90	60	11.25	11.48
	1931	252	90	60	10.00	11.01
Total of 26 tests				Average	10.11	10.55

for two doses. Seven tests harvested in 1934, comparing 102 pounds of nitrogen divided into three doses, with two doses in the last applications of short ratoons, gave in tons of sugar per acre *7.66* for two and *7.72* for three.

The time-~~of-application-of-nitrogen~~ tests, although fewer in number, are interesting. ~~In~~ Table IV will be found the amounts of nitrogen and age at which these were applied. The results of the tests are also found in that table. They show how strikingly different yields may become when nitrogen is not applied at the proper time. As was later found out, applications of nitrogen as large as those used in these tests were better divided into two, and we can see from Experiment 56 that the dividing of the first 120 pounds into two doses was a better practice. We can also see from a study of the age of cane (given in Table IV in parentheses following the amount of nitrogen) that the best yields resulted when the largest amount of nitrogen went on in the "boom stage" of growth, or from about three to ten months of age. When too much went on, too early or too late, the yields as well as the juice quality suffered.

These tests also show that if the period between the last first-season application and the first second-season dose was too long, and this was still within the

TABLE IV

TIME OF APPLICATION OF NITROGEN AT PIONEER

Expt.	Treatment	Pounds of N. per Acre — 1st Season 1	2	3 (Nov.)	2nd Season 4 (Feb.)	5 (Apr.)
55	N	120 (3)	0	0	120 (9)	0
	O	120 (3)	0	120 (6)	0	0
	P	60 (3)	0	60 (6)	0	120 (11)
	Q	120 (3)	0	60 (6)	0	60 (11)
56	N	50 (2)	70 (4)	0	120 (10)	0
	O	50 (2)	70 (4)	120 (7)	0	0
	P	50 (2)	10 (4)	60 (7)	0	120 (12)
	Q	50 (2)	70 (4)	60 (7)	0	60 (12)
57	N	100 (3)	20 (4)	0	120 (10)	0
	O	100 (3)	20 (4)	120 (7)	0	0
	P	100 (3)	0	20 (7)	0	120 (12)
	Q	100 (3)	20 (4)	60 (7)	0	60 (12)

Figures in parenthesis signify months of age when applied.

Results:

	Expt. 55 T.C.	Q.R.	T.S.	Expt. 56 T.C.	Q.R.	T.S.	Expt. 57 T.C.	Q.R.	T.S.
N	67.35	7.96	8.46	74.68	8.74	8.54	51.71	6.88	7.52
O	58.52	8.03	7.29	77.28	8.51	9.08	47.74	6.72	7.10
P	57.81	7.95	7.27	71.82	8.81	8.15	39.74	6.92	5.74
Q	59.01	7.55	7.82	73.78	8.72	8.46	44.04	6.88	6.40

"boom stage" period of growth, there was a big curtailment in yield. Other tests have shown that if too long a period elapses between the two second-season applications, forcing the last one late into the spring, there is also a loss in yield due to poorer juices because of the late application. The time of year these applications can be made, very early or later, the time the crop will be harvested and the age of cane should all govern the period when these applications should be made. A longer period should elapse between these applications when the first is applied very early, and yet if the crop comes off early the next year these applications should come closer. Under Pioneer conditions, the writer feels that 100 pounds of nitrogen the second season is about the maximum that should be applied, unless the crop was started very late the year before and is to be cut late the next crop.

In a later series of tests on placing fertilizer with the seed, it was shown that this was a great help ~~for maximum~~ yields. It was also shown that as little as 25 pounds of nitrogen with the seed and 25 pounds one month later, when compared with placing 50 pounds on one month after planting, carried a significant gain in sugar and juice quality through to harvesting. Other tests on applying the larger share of nitrogen in the "boom stage" gave better yields for these treatments. It also became quite apparent that the soil type and time of year were very important considerations as to the time to apply nitrogen. The open, porous soils with poorer water-holding capacity required smaller doses applied oftener. The tight, fine silt

soils could stand large applications. The boom stage of growth started much sooner in later cut fields than in very early cut fields, and much sooner in the hotter Lahaina and Olowalu sections than in the upper sections of Puukoli, Wahikuli and Honokawai. Variations were therefore tried out in the different fields and sections so that today we find quite a range of practices in vogue.

An average of four tests comparing nitrate of soda with leunasalpeter in the second season of 1929 and 1930 gave the following figures:

	T. C.	Q. R.	T. S.
Nitrate of soda	52.90	7.24	7.33
Leunasalpeter	56.13	7.34	7.63

An average of four tests comparing calurea with sulfate of ammonia in the second season of 1932 gave:

	T. C.	Q. R.	T. S.
Calurea	65.92	7.1	9.26
Sulfate of ammonia	71.25	7.2	9.93

Averaging twenty tests comparing nitrate of soda with sulfate of ammonia in the second season in the 1930 to 1933 crops gave:

	T. C.	Q. R.	T. S.
Nitrate of soda	74.40	7.58	9.86
Sulfate of ammonia	75.66	7.67	9.92

Many of these last tests were studied for changes in pH due to fertilization. More often than not the sulfate changed the pH towards the alkaline side, but a general trend in some tests seemed to be only very slightly towards acidity. In the light of work done in other crops and in sugar cane at Oahu Sugar Company, Limited, the use of ammoniacal nitrogen has a very decided influence on the uptake of phosphates. So in areas very deficient in phosphates, like many of those at Pioneer, this is a decided secondary benefit to cane yields.

Molasses

Since the use of molasses as a fertilizer is so closely tied up with nitrogen, the discussion on this material is brought in at this point.

With the use of molasses in the irrigation water applied to fields, it became imperative to apply sulfate of ammonia along with the molasses to prevent a check in cane growth through denitrification in the soil set up by the microbiological decomposition. But from the first test harvested in 1924, it was apparent that the percentage response to molasses was greatest where the nitrogen was limited, showing that the nitrogen in molasses must be of value. It has also been apparent ever since this first test, that optimum nitrogen applications were necessary to give larger yields. In areas where the nitrogen had a tendency to be produced in large quantities or was found in greater quantities, this application of molasses had a decidedly depressing effect on juice quality. On exceedingly porous or gravelly soils the application of large amounts of molasses had a very beneficial effect on yield and ratooning. Much of this is undoubtedly due to the improvement in water-holding capacity of these soils. On the other hand, there are areas of very fine, silty

red soils that can be harmed by heavy applications of molasses. This is no doubt brought about through the same agency that benefits the soil types just mentioned above. The tightening of these soils so that water cannot penetrate to the cane roots will naturally depress cane growth for a period of time. This may be more marked in areas of straight lines on grades where the water will have a tendency to run too fast due to this tightness. As the cane grows older the roots may open up the soil, the trash may slow down the water flow and the plant and water both remove some of the controlling features of the molasses in the soil, so that the crop area will show a decided improvement in growth as if some unknown application of material had been made.

On the whole, however, molasses has been shown to have a wonderful effect on soil fertility equal to the effect of fallowing land for several years. The analyses of soils at periodic dates after application of molasses at Pioneer have shown a tremendous improvement in available plant foods. These points were very thoroughly covered by the writer in articles on "Molasses as a Fertilizer" in the Proceedings of the Hawaiian Sugar Planters' Association for 1927 and 1928. In areas of heavy nut grass it seems as though there should be at least three bags of sulfate of ammonia applied with the molasses instead of the regular two.

Phosphate

In the thirty or more amounts-of-phosphate-to-apply tests harvested, which are listed in Table V, it has been clearly shown that in the areas that were deficient in this nutrient by soil analyses, there has been a distinct response to phosphate up to 200 pounds per acre. In some areas there have been responses to larger amounts, and in still other areas there have been responses only to smaller amounts. On the whole, the areas very low in phosphates in the crusher juice show distinct responses to phosphates.

The later tests, on amounts of phosphate installed in new locations, have not shown as large responses to phosphate as the earlier ones. This is undoubtedly due to the larger applications to plantation fields in later years creating a reserve supply, while the earlier fields had no reserve because of very small applications of phosphate in the past. This would strongly indicate that phosphate reserves can be built up within a few years, by using fair amounts of phosphate. The question now arises on how we may make use of this reserve in economizing on fertilizer. In amounts-of-phosphate tests, where there is no distinct deficiency of phosphate, we often find poorer juices with increased applications. The opposite is often the case where a real deficiency of phosphates is found. Under the latter conditions, the writer feels that it would be most advisable to put part of the phosphate on in the second season or apply extra phosphate at that time.

In a series of five experiments harvested twenty-two times, it has been clearly shown that superphosphate was distinctly superior to reverted and raw rock phosphates. Table VI shows these figures in detail. Even when 300 pounds of phosphate per acre are used, the difference in cost of super and raw rock furnishing this would be made up three times in the price of increased sugar per acre obtained from super over raw rock. A study of the figures does not show any equalization of the yields of the super and raw rock plots even after ten years. This shows that there is no more residual phosphate in the raw rock plots than in the super.

TABLE V

TONS OF SUGAR PER ACRE IN PHOSPHATE EXPERIMENTS AT PIONEER MILL COMPANY

Expt. and Field	Year	Plant Food N	Plant Food K_2O	Pounds per Acre 0	50	100	150	200	300	400
3 (B6)	1921	200	0	6.24	6.04	6.26	**6.41**			
	1923	200	0	6.61	6.76	7.29	**7.61**			
	1925	200	0	6.08	6.72	**7.09**	6.92			
45 (LA7)	192[illegible]	240	100			11.37		**12.21**	11.97	
	1928	260	250					**9.95**	9.87	7.57
	1930	260	250			12.03		**12.27**	10.86	
	1931	263	250			8.89		**10.43**	9.76	
67 (B3)	1928	240	150	12.73		13.13		**13.14**	13.02	
	1930	240	150	10.67		11.47		11.71	**11.87**	
50 (E2)	1927	240	100	9.61		10.65		**11.18**	9.82	
	1929	260	250			12.56		12.68	**13.43**	12.56
	1931	260	200			12.04		12.27	**12.55**	11.82
51 (B7)	1927	240	100	10.02		9.96		10.00	**10.58**	
	1929	260	250			13.23		12.90	**14.04**	13.44
	1931	260	200			12.30		12.83	13.25	**13.36**
	1933	253	200			12.27		**12.66**	12.37	12.34
52 (B4)	1927	240	100	10.58		10.11		10.61	**11.20**	
	1929	260	250			10.53		10.44	**10.73**	10.49
53 (33)	1927	240	100	12.14		12.23		**13.01**	12.50	
	1929	260	250			10.53		10.44	**10.73**	10.49
	1931	260	200			10.25		10.24	10.26	10.10
	1933	253	200			8.81		8.46	8.84	8.42
54 (F2)	1927	240	100	10.12		10.92		**11.25**		
72 (G2)	1930	260	250			10.55		10.77	**11.15**	10.89
79 (C3)	1931	260	250				8.69	8.94	**9.12**	
82 (30)	1932	260	250				11.89	11.75	**11.96**	
90 (B6)	1932	256	250				**14.78**	14.43	14.47	
	1934	256	250				12.46	**12.58**	12.45	
94 (34)	1933	253	200			10.63		10.66	**10.77**	
99 (E1)	1933	253	200			10.47		**11.33**	10.78	

Bold faced figures show the highest yielding treatment.

A Mitscherlich pot test run on the soils of one of these tests (Experiment 24 in Field G2) after the fifth harvesting in 1932, or nine years after the test was started, shows available phosphate of over 500 pounds per acre-foot for super and 47 per acre-foot for raw rock. The K_2O figures are 345 for super and 445 for raw rock. All five of these tests have had one soil analysis made by the one per cent citric acid method during the life of the crop and after the tests have been about eight years old. These indicate differences of higher pH and higher lime and potash contents for the raw rock treatment. The crusher juice figures all have lower K_2O contents for the raw rock plots over the super. The continued use of raw rock therefore seems to build up potash in the soil by not allowing it to be removed in the cane crop. The Mitscherlich tests therefore showed this increased potash. Another pot test was run at Pioneer with sudan grass on soil from Experiment 21 in Field LA7. Surface and subsoil were taken from the super and raw

TABLE VI

FORMS-OF-PHOSPHATE EXPERIMENTS AT PIONEER

Expt. and	Crop	Plant Food			Super			Reverted			Raw Rock		
Field	Year	N	P_2O_5	K_2O	T.C.	Q.R.	T.S.	T.C.	Q.R.	T.S.	T.C.	Q.R.	T.S.
12 (B4)	1925	180	100	0	90.8	6.40	14.20	90.2	6.40	14.10	88.2	6.58	13.20
	1927	190	150	100	71.3	7.06	10.10	71.8	7.01	10.23	67.1	6.96	9.63
	1929	260	300	250	60.4	6.76	8.93	62.1	6.77	9.17	60.1	6.88	8.74
	1930	260	250	200	44.7	6.73	6.64	46.5	7.00	6.65	43.9	6.73	6.53
15 (32)	1925	180	100	0	83.9	7.20	11.65	82.4	8.10	10.18	81.5	7.20	11.31
	1927	190	150	100	67.8	8.15	8.32	69.2	8.16	8.48	66.0	8.08	8.16
	1929	260	300	250	68.3	6.65	10.27	67.0	6.71	9.99	67.7	6.65	10.18
	1931	260	250	200	76.2	7.33	10.40	72.4	7.26	9.97	72.2	7.34	9.84
21 (LA7)	1925	180	100	0	94.5	7.30	12.94	96.6	7.20	13.41	97.1	7.09	13.70
	1927	190	150	100	79.4	7.18	11.06	75.6	7.24	10.44	72.1	7.10	10.15
	1928	260	300	250	57.6	8.17	7.05	56.8	7.75	7.33	51.4	7.72	6.65
	1930	260	250	200	75.9	7.70	9.86	78.1	7.80	10.01	74.1	7.90	9.38
	1931	263	300	250	64.8	7.64	8.48	67.8	7.85	8.64	64.0	7.85	8.15
24 (G2)	1925	177	100	0	76.2	6.23	12.22	67.8	6.30	10.78	70.4	6.30	11.18
	1927	240	150	100	75.4	7.90	9.53	79.3	8.22	9.65	78.6	7.87	9.99
	1928	260	300	250	65.5	7.67	8.55	64.0	7.24	8.85	65.4	7.02	9.31
	1930	260	300	250	78.1	7.40	10.55	77.2	7.30	10.58	70.9	8.30	8.65
	1932	256	300	250	94.6	8.31	11.38	88.9	8.16	10.89	95.9	8.44	11.36
	1933	256	300	250	64.3	7.00	9.19	56.3	6.86	8.21	59.8	6.76	8.85
47 (E2)	1927	240	150	100	81.7	7.78	10.51	80.1	7.80	10.28	82.1	7.73	10.62
	1929	260	300	250	86.3	6.63	13.01	84.2	6.70	12.57	83.3	6.66	12.51
	1931	260	250	200	88.7	6.80	13.05	86.9	6.95	12.50	79.2	6.76	11.72
Average of 22 tests....................					74.8	7.27	10.36	73.7	7.31	10.13	72.3	7.27	9.99

rock plots and treated with super and raw rock in the combinations listed below. The yields in grams per pot are also given:

	Expt. Treatment	Pot Treatment	Yield
Surface soil	super	super	530
	super	raw rock	550
	raw rock	super	678
	raw rock	raw rock	500
Subsoil	super	super	646
	super	raw rock	608
	super	none	576
	raw rock	super	540
	raw rock	raw rock	424
	raw rock	none	468

What is it that seems to be depressing the soil productivity by continued use of raw rock?

In two tests comparing treble superphosphate (A), raw rock (B), ammophos (C), and a mixture of these three, half of which is raw rock (D), the results are as follows:

	T. C.	Q. R.	T. S.
A	68.9	6.67	10.33
B	65.2	6.61	9.86
C	72.4	6.68	10.84
D	70.1	6.66	10.53

	T. C.	Q. R.	T. S.
A	90.6	7.37	12.29
B	85.1	7.29	11.67
C	91.8	7.36	12.47
D	85.9	7.29	11.78

On the strength of these last two tests the plantation's mixed fertilizers were changed from one like treatment D above to newer ones using ammophos predominately. This change had been attempted before, but because of changes in fertilizer prices during the absence of the writer in Puerto Rico, a return to the raw rock-super mixture was made.

Besides all the amounts-of-phosphate tests, there are the many plant food or PK tests which show very clearly the value of phosphates to many of the fields of Pioneer Mill Company.

Potash

The twenty harvestings of amounts-of-potash tests, listed in Table VII, show that on the whole there is no uniform demand for potash, but that in certain areas a very marked response can be secured for potash applications over and above the 120-pound mark used in the past. This has been made use of in recent changes of fertilizer policies so that on these deficient areas the application has been raised to a minimum of 175 pounds. Very unfortunately, a few years ago Experiment 64,

TABLE VII

TONS OF SUGAR PER ACRE IN POTASH EXPERIMENTS AT PIONEER

Expt. and Field	Crop Year	Plant Food N	Plant Food P_2O_5	Pounds per Acre 0	60	120	180	240	300	360
40 (O8)	1926	180	100	8.9	9.83	9.06	**9.93**			
	1928				11.70		11.76	**12.30**		11.83
46 (E1)	1927	240	90	7.4	**8.87**					
67 (B3)	1928	240	200	**13.74**		13.46	13.20		12.58	
	1930	240	200	**11.53**		11.43	11.38		11.14	
64 (G3)	1927	240	200		10.71	11.06	11.46	**11.77**		
	1928	260	300		9.76	**10.27**		10.06	9.21	
	1930	260	300		11.22	11.88		11.60	**12.06**	
	1932	256	300		10.94	12.04		**12.32**	12.02	
	1933	256	300		9.91	10.57		**10.80**	11.17	
69 (MA6)	1929	260	300		11.21	12.52		**13.06**	12.17	
	1931	260	250		10.57	**10.82**		10.33	9.96	
70 (32)	1929	260	300		12.37	**12.73**		12.61	13.16	
	1931	260	250		11.16	**11.60**		11.21	11.23	
	1933	256	250	**11.35**	11.12	11.15		10.99		
71 (E2)	1929	260	300		10.23	10.73		**10.82**	10.75	
	1931	260	250		11.28	11.46		**11.68**	11.35	
	1933	256	250	9.90	10.10	10.41		**10.71**		
80 (C3)	1930	260	300	**8.43**		8.45		8.10	8.46	
81 (LA7)	1931	263	300	8.04		8.26	8.19		**9.14**	
	1933	256	300	10.95		10.76	10.89		**12.59**	
	1934	260	300	6.45		6.93	8.31		**8.49**	
83 (30)	1932	260	300	11.36		11.76	**11.91**		11.79	
88 (B6)	1932	256	300	12.59		**13.76**	13.14		13.51	
	1934	256	300	10.85		**11.44**	11.27		11.25	
95 (34)	1933	253	250	8.64		8.60	**9.12**		9.11	
B1	1934	252	207	9.44		**10.18**				
4 (B3)	1921	200	0			7.31		**7.36**		
	1923	200	0			7.31		**7.81**		
	1925	200	0			7.01		**7.11**		

Bold faced figures represent the highest yielding treatment.

which should have been a key experiment for areas low in potash by soil analyses, was laid out with the plots labeled in the reverse order to the usual method in labeling increased amounts of a material. The plots were labeled D, C, B, A, for increasing amounts of potash. On the next crop fertilization, these plots were fertilized without reference to this method of labeling as the stakes were all in and the fertilizer was put on in the usual method of increased amounts as the letters went down the alphabet. The residual effect of the first crop fertilization was all evened up as a study of the yields in 1927 and 1928 will show (Table VII). During the next few months the plot labels were all changed to V, W, X and Y and the maps were also changed, but no comment was made in any of the notes on this experiment. The writer, however, was aware of this at the time of fertilization and recorded it in his notes. In spite of this reversal of plots you will please note the distinct response to potash in a more marked degree as each succeeding crop was harvested.

TABLE VIII

TONS OF SUGAR PER ACRE IN PK EXPERIMENTS AT PIONEER

Expt. and Field	Crop Year	Plant Food N	P_2O_5	K_2O	N	NP	NK	NPK
4 (B6)	1921	200	100	100	7.19		7.33	7.57
	1923	200	100	100	6.97		7.56	7.53
	1925	200	100	100	6.91		7.06	7.48
7 (B2)	1924	180	100	50	8.99	9.27	9.15	9.31
	1926	180	100	50	6.43	7.15	6.96	7.20
	1928	240	200	150	6.43	7.83	6.46	7.42
8 (31)	1924	180	100	50	12.11	12.62	12.42	12.22
	1926	180	100	50	7.77	8.96	7.62	8.53
	1928	240	200	150	6.04	7.50	6.11	7.56
	1930	260	300	250	5.95	7.76	6.10	7.54
13 (B4)	1925	180	100	50	13.45	13.10	13.07	13.75
	1927	190	150	100	9.45	9.60	9.12	9.23
	1929	260	300	250	7.17	8.39	7.48	9.09
	1930	260	250	200	5.30	6.39	5.48	6.73
17 (32)	1925	180	100	50	10.16	9.89	9.65	9.95
	1927	190	150	100	6.62	8.03	6.65	7.76
	1929	260	300	250	7.24	8.12	7.24	8.41
	1931	260	250	200	6.98	9.14	7.34	9.77
20 (LA7)	1925	180	100	50	13.87	13.81	14.11	13.70
	1927	240	150	100	10.08	12.36	11.92	11.17
	1928	260	300	250	7.14	7.82	6.47	8.27
	1930	260	300	250	9.01	9.71	8.96	10.12
22 (G2)	1925	177	100	50	9.93	10.88	10.59	10.60
	1927	240	150	100	8.80	9.38	9.28	9.95
	1928	260	300	250	9.17	8.70	8.58	9.25
	1930	260	300	250	7.40	9.97	7.51	10.25
26 (O8)	1925	180	100	50	9.08	9.24	9.90	9.14
	1926	180	100	50	7.10	7.39	7.56	7.39
	1928	240	150	100	8.88	8.81	9.06	8.62
31 (A5)	1926	180	100	50	5.50	6.22	6.10	6.15
	1928	240	200	150	5.19	5.04	4.95	6.26
33 (B1)	1926	180	100	50	16.12	15.07	15.73	15.52
	1930	260	300	250	9.82	10.51	11.20	10.99
35 (30)	1926	180	100	50	8.38	10.47	9.25	10.47
	1928	180	200	150	7.22	10.09	7.12	10.42
	1930	260	300	250	6.62	11.30	6.63	11.34
37 (C3)	1926	180	100	50	10.65	10.85	10.05	10.40
	1928	240	150	100	10.93	11.21	11.23	11.50
	1930	260	300	250	8.71	9.68	8.84	9.54
48 (E2)	1927	240	150	100	8.98	8.32	8.10	9.25
	1929	260	300	250	11.05	11.46	12.13	12.73
	1931	260	250	200	9.17	11.03	9.49	11.68
63 (LB6)	1929	260	300	250	11.09	11.15	11.21	12.00
	1930	260	250	200	9.18	10.20	9.99	10.63
30E	1928	228	300	200		9.77	7.17	10.32
A3	1928	240	250	200		6.44	5.45	6.08
F4	1928	240	250	200		8.48	8.04	8.86
C2	1927	230	300	250		7.11	6.81	7.62
	1929	230	300	250		8.56	9.34	9.35
Average of those having all four treatments					8.76	9.62	8.94	9.80

The areas that were markedly deficient as shown by the old one per cent citric acid analyses in the 1922, 1926 and 1927 surveys are the very ones that show the large responses to increased potash. The G3, E2 and LA7 tests have continued to show what might be gained by higher potash applications in those districts.

In considering the potash found in pump waters as an available nutrient for plant growth, as mentioned above in comment on crusher juice analyses, one must remember that Maui waters are very high in pounds per million gallons. This is not true of pump waters on Oahu, and therefore what might be true of making use of the potash in these waters on Maui might not be true on Oahu.

Plant Food Balance

The fifty harvestings of experiments on N, NP, NK and NPK treatments are listed in Table VIII and averages arrived at for only those having all four treatments. It is again very interesting to show that there is a decided loss from nitrogen only, and that there are gains from both phosphate and potash on the average soil; but in arriving at a fertilizer policy each individual case deserves study and proper handling. It is of particular interest to point out a few of these tests in the list.

Experiment 48 in field E2 checks very nicely with other tests in this section of the plantation in showing the necessity of potash as well as phosphate in this soil type. Experiments 22 in G2, 20 in LA7, 13 in B4 and 17 in 32 all show this same point. The very marked increases for phosphate are the most prominent points in this table and readily check with other fertilizer results. However, the writer wishes to call your attention to Experiment 35 in field 30. The enormous differences in the phosphate treatments over the others can hardly be comprehended unless one really saw these tests in operation. The test was of such interest that quite a study was made of soil analyses and plant material analyses. It would require too much space and time to go into a discussion of these studies at this time, and since they were conducted along with similar tests in other areas, the comments should be reserved for a complete write-up. The writer felt that it would be of interest to return to the various plots the amount of fertilizer each had not received in comparison with the NPK treatment in the three crops, that is, the N plots would receive in one application all the phosphate and potash that the NPK plots had received in the three crops and so on throughout the other treatments NP and NK. There were, however, two of the seven plots in each treatment given the normal plantation fertilizer for the field. In the writer's opinion, some mistake was made in labeling the plots receiving only the plantation practice, and since the staking and mapping of the test was not completed till six months later, there is no way of settling the matter.

The average yields of each series of plots, regardless of whether it received only plantation practice or the increased plant food, are given herewith:

	T.C.	Q.R.	T.S.
N	88.2	7.67	11.55
NP	98.9	7.89	12.64
NK	89.7	7.92	11.32
NPK	95.7	7.82	12.24

Comparing these yields with those of the last crop and noting the percentage gains in sugar, we have:

	Tons Sugar per Acre 1930	1932	% Gain
N	6.62	11.55	74.5
NP	11.30	12.60	11.5
NK	6.63	11.32	71.0
NPK	11.34	12.24	7.5

The two poorer yielding treatments of the 1930 harvest have not regained the yielding power of the higher or phosphate treatments. This clearly points out that one cannot bring a field up to its maximum production within a crop, but that the effect is cumulative from residual fertilization. Many of the tests at Pioneer have clearly brought out this point, and in the writer's opinion the reverse idea must be true as well. In other words, if the yield is high from proper fertilization and one decides to economize on fertilizer, he may secure as fine yields within the range of probable error for a crop or two, but eventually the soil reserves will have been depleted to a point at which yields will drop materially.

In a closer study of these various tests and all other fertilizer tests at Pioneer, it is quite apparent that where proper amounts of plant food are used, yields are maintained at a high level through several crops. Where there are insufficient plant foods there are often very marked decreases between crops. This is true even for nitrogen as well as for the others. The smaller applications in plant food may show a decrease in yield gradually, but often show a rather abrupt one when the drain on soil reserves has reached a point at which it becomes almost impossible for the plant to secure the food. Crusher juice analyses have often shown a greater uptake of phosphates and potash when nitrogen only has been applied, than when all three plant foods are used.

In a study of the time to apply the mixed fertilizer, two tests were harvested comparing a complete fertilizer (A) vs. only phosphate and potash (B) vs. nothing with the seed (C). The latter treatment received its complete fertilizer one month later, and at the same time, the second treatment received its 50 pounds of nitrogen. The results of these two tests are interesting and are given herewith:

	T.C.	Q.R.	T.S.	T.C.	Q.R.	T.S.
A...........	84.20	7.4	11.38	90.79	6.6	13.76
B...........	87.44	7.4	11.82	96.65	6.6	14.64
C...........	80.61	7.4	10.89	95.89	6.7	14.31

These show how important it becomes to have phosphates and potash applied early. Similar tests on other plantations have clearly demonstrated this point, and the writer has drawn attention to this in other papers, showing that much depends on whether there is a deficiency of these elements or not. These figures also bring out the point that 50 pounds of nitrogen, or part of it, could be more effective at a later period. This was also shown in the test mentioned above having 25 pounds of nitrogen with the seed and 25 pounds one month later, in comparison with the 50 pounds applied one month later. (Both treatments received phosphate and potash with the seed.) As mentioned above, the significance of the gain in quality

and sugar for the 25 pounds with the seed was large; that fact then, coupled with these results, shows that 25 pounds of nitrogen with the seed is about the most profitable.

Several comparisons of the new, more concentrated fertilizers with the older forms gave yields in favor of the newer materials even when less plant food was applied with the new. A list of these follows:

Materials	Old	New
P.M.S. vs. A5....................	6.99	7.14
P.M.S. vs. A5....................	10.21	11.25
P.M.S. vs. A5....................	9.39	10.31
P.M.S. vs. A5....................	8.86	9.06
P.M.S. vs. A5....................	7.97	7.69
H.G. vs. A4......................	8.83	8.64
H.G. vs. A4......................	8.85	8.25
H.G. vs. A4......................	8.10	9.07
P.M.S. vs. A4....................	13.08	14.58
A6A vs. A17 + N.K..............	8.31	7.99
A6A vs. A17 + N.K..............	9.66	9.27
A6A vs. A17 + N.K..............	6.66	7.47
A6A vs. A17 + N.K..............	8.83	9.38
A6A vs. A17 + N.K..............	8.78	8.12
A6A vs. A17 + N.K..............	8.89	8.78

In the last series of the above comparisons, the plant food was 20 pounds of nitrogen, 12 pounds of phosphate and 11 pounds of potash less per acre, and the difference was all in the first three months of the crop. On the whole, the newer more concentrated fertilizers are much more economical to handle and give better returns.

A series of triangle fertilizer tests, after the plan of Schreiner of the United States Department of Agriculture, was harvested at Pioneer. Four of these were reported upon in the Technologists' Proceedings for 1930. Two more harvestings were subsequently made. All of these tests very clearly pointed out the vast differences in yield one can secure from different plant food balances. They also showed the differences in response to nitrogen, phosphate and potash on the various soil types of the plantation. They checked very nicely with other experimental data in showing the areas very deficient in certain plant foods. In general, these tests showed the best results from a ratio of about 250 pounds of nitrogen, 200 pounds of phosphate and 150 pounds of potash. Therefore, in the writer's opinion, it would be necessary to increase all three plant foods at the same time in attempting to find the optimum amount of each plant food to apply. This type of test has been harvested several times at Olaa in the last crop or two and has shown some very interesting results. Gains in cane and sugar without poorer juices were made with significant differences, but they were not economical. The point that should be emphasized is that quality of juice was not affected. This has always been the writer's contention, that when a proper balance of fertilizer is obtained,

quality will not be radically affected with increases in plant food, as has been demonstrated in many tests at Pioneer, as well as elsewhere.

Olowalu Section.

Since this part of the plantation has only been under the supervision of Pioneer Mill Company in the last few years, the results of the tests harvested on those fields have not been averaged in all cases. Therefore a few comments on these soils alone are given herewith.

In a number of tests at Olowalu on amounts of phosphate, a high significance was found in better quality of juice without phosphates, while in three others with amounts of potash, a better quality was obtained with potash. In plant food tests on Olowalu soils, it has been demonstrated that nitrogen alone up to a little over 200 pounds per acre has given about the best yields. There is, however, an enormous response to large applications of filter cake and molasses. These must have altered the water-holding capacity of the soils and thus increased the yields. There are, however, in the pali lands soils of a different nature from the washed-in silt and gravel of the flats in Olowalu, and these will undoubtedly respond to a different fertilization. It must be remembered that the cropping cycle on these fields is a short one due to the slowing down of growth after a certain age has been attained; for this reason high applications of nitrogen do not seem to pay.

Mitscherlich Pot Studies

Several Pioneer soils have been studied by this method in the last few years. Many of these have been from experimental areas where distinct responses to fertilizers have been obtained. The results of these pot tests correlate very nicely with other data and show areas where potash and phosphate are low. The large responses to phosphate in many of these early harvestings at Pioneer have made these soils especially valuable to the Mitscherlich investigations, and much of their correlation data have been obtained from these soils. These pot tests have not given us many additional data when compared with the vast amount of data collected in the past from soil analyses, juice analyses and experiments, but it is interesting enough to note that they do correlate with these other data.

New Developments

A very extensive soil kit analyses—juice analyses—yield-of-crop data—correlation study is now under way. This will be well worth watching and should aid us in a policy of differential fertilization in parts of fields and should also help to bring up the general averages of fields.

Conclusions

In concluding an article of this nature, one could make a very broad statement to the effect that the results of fertilizer experiments have been almost entirely responsible for the changes in fertilizer policy on the plantation. It would have been very improbable and almost impossible to have made these changes without

the aid of field experiments and the contributory data secured from them, but a few points should be summarized to properly conclude the paper.

1. Experimental data have confirmed the general broad groupings of fields through soil surveys and crusher juice analyses and vice versa; the three lines of investigation having gone ahead simultaneously.

2. Experimental data have strongly indicated better yields from better utilization of the plant foods in the following ways:

A. Nitrogen:
1. Increased amounts to suit location, soil type, water supply, etc.
2. Several applications in both seasons, that is, at least three in the first and two in the second.
3. A greater share of nitrogen in the "boom stage" of growth.
4. Proper balances of other plant foods.
5. Proper time of application so that the first second-season fertilization should not be delayed too long after the last first-season one or too late in the "boom stage." (A delay here is a sure way to decrease yields.)
6. When applications of N are 50 pounds per acre the period between doses should be varied to suit the time of year. In the second season, this period should be more than one month when the first dose goes on in January or February.
7. Use of ammoniacal in preference to other forms of nitrogen.
8. Utilization of nitrogen from filter cake and molasses.

B. Phosphate:
1. Increased amounts to suit deficiencies as shown by experiments, soil analyses or crusher juice data.
2. More available forms such as super or ammophos.
3. Use of ammoniacal nitrogen.
4. Utilization of phosphates in filter mud.

C. Potash:
1. Increased amounts to suit deficiencies as shown by experiments, soil analyses or crusher juice data.
2. Utilization of potash from molasses and pump waters.

D. Balance of plant foods:
1. Better yield and juice quality when used in proper ratio to each other.
2. When used in sufficient amounts, yields are maintained. (This has been demonstrated in the big decreases between crops of plant and ratoon cane when there is insufficient plant food, while in other cases where plant foods are abundant there may be increases in yield.)

3. Strong indications are apparent that with proper fertilization good yields may be built up and maintained. The residual effect of fertilizer is more marked than we normally think. To bring back an area depleted of plant foods requires

more time than just one crop heavily fertilized. In other words, the effect of proper fertilization is cumulative. The reverse of this fact should also be stressed in these times when much consideration is being given to reduced fertilization in an attempt to save a few dollars in cost.

The able staffs of both the Pioneer Mill Company and the Experiment Station of the Hawaiian Sugar Planters' Association have been responsible for the carrying out of these experiments; much credit is due them for this work, and their results have been of valuable assistance in determining a proper fertilizer policy for the plantation. The work is not over yet and you will undoubtedly hear from the others today as to how the future policies will be changed and improved through further research. You can readily see the immense value such an amount of research can be in shaping the plantation practices, and the writer sincerely hopes that this may act as a stimulus to further experimentation on other plantations.

The Present Trend in Our Use of Fertilizer*

By R. J. Borden

The present trend in fertilizer usage on the sugar cane lands of these Islands is very definitely towards a differential fertilization; hence this discussion will center chiefly about some of the facts that are concerned with the adoption of a policy of differential fertilization.

In a general way, however, we begin to note some reduction in the total amounts of fertilizer being applied, especially in phosphate, in instances where more recent evidence has shown no gains from its application, and where soil analyses have indicated an apparent sufficiency of this plant food. There has not been much change in the total potash applications. A slight drop of perhaps 20 to 40 pounds in the nitrogen, chiefly in the later applications, has been noted on a number of plantations. There have been very few increases in the total amounts of any of the plant foods that are being applied, although there have been some adjustments in the distribution of these nutrients in an attempt to put more on some specific areas and correspondingly less on others. Evidently we have reached a peak in the total amounts per acre and the general trend will henceforth be downward.

We note a general reluctance, however, to accept a policy that calls for decreasing the present total fertilizer applications. This is perhaps very commendable, until such time as good evidence is presented to prove the economy of such a move. Most certainly should we approach this question of cutting down fertilizer applications in the same careful way that was formerly used when we decided to increase

* Presented at a meeting of the Maui section of the Association of Hawaiian Sugar Technologists, Agricultural Division, Lahaina, Maui, March 14, 1935.

the amounts to be applied. Hence, we feel quite strongly that each case needs individual study, and I want to discuss with you today just a few of the things that will have to be considered.

Phosphate

First let us consider phosphate: a material that is rapidly fixed and therefore not subject to waste by luxury consumption or by leaching; which is needed in relatively small amounts but is very necessary in these small amounts; and which applied to our high phosphate-fixing soils in small amounts, is undoubtedly very ineffective in causing immediate increased yields. What should guide our policy with regard to phosphate fertilization: (1) A realization that it is perhaps easier to deplete the available phosphate reserve in our soil than it is to build it up. (2) A recognition of the fact that money invested in phosphate is a soil investment for the future and not simply a chargeable item of expense against the next crop to be cut. (3) A knowledge of the fact that there is little evidence to show that too much phosphate is harmful to the cane crop. (4) A knowledge that phosphate fertilizers are generally fixed by the soil at their point of application and that they should be put where the greatest number of feeding roots will be apt to contact this phosphate-satisfied soil. These points would tend to argue for ample phosphate applications, particularly at the time when the field is plowed and planted. Against this argument we have the one that says, "if the available supply of phosphate for this present crop is sufficient, we may leave phosphate out of the present crop fertilization." Is this sound? We have been advised for ages past that the storehouse of plant food (which includes phosphorus) in the soil is not inexhaustible, and that which we take out in the crop, we must ultimately return. If this is good logic then we ought to be able to square ourselves with Nature if we put back approximately 100 pounds of phosphate which our normal crop takes away. If you have been putting on this amount, or more, for some years past, then you have built up a reserve, and under the present economic conditions, you are just as much entitled to draw on this reserve as your plantation directors were entitled this year to pay unearned dividends from their reserve funds. If you have been building up the available phosphate in your soil, either by applications of phosphate in fertilizer materials or from filter cake (and remember that a 5-ton dressing of filter cake will put 100 to 150 pounds of P_2O_5 back), then you are indeed in a position to let your phosphate insurance carry you over. Also, if Nature is providing your soil with a sufficiency of available phosphate, I believe it would be wise to make use of it now, particularly for your ratoon crops, and think about a possible phosphate refund to your soil when the next plant crop goes in.

Where the evidence quite definitely indicates a phosphate deficiency, there should be, and generally is, no hesitation about applying phosphate fertilizer, but we should stand ready to face the facts as we find them and meet them accordingly.

Potash

With regard to potash, we have quite a different plant food material to consider. The volcanic lavas from which our soils have been formed contain a large amount of potash, but the weathered soils from this lava have lost about 60 per cent of this

potash. Analyses of cropped mauka soils compared with virgin mauka soils show that more of the potash has been lost from the cropped soil than can be accounted for in the crops removed. Thus it appears that available potash, if not taken up by the crop, is subject to loss by leaching. Maxwell makes the statement that the analysis of drainage waters from Hawaiian soils shows potash lost in this manner that is fully equivalent to that taken up by the crops. F. E. Hance's studies on the irrigation waters from central Maui show us the fate of the potash that has become available in the Island soils. The sugar cane crop takes up a large amount of potash from the soil. Analyses have shown this to be 600 to 800 pounds per acre, with perhaps half of it removed from the field when the stalks go to the mill. We have a feeling that a large part of the total potash taken up by the plant is taken up in luxury consumption simply because it is available in the soil solution. Surely we do not need to contribute purchased potash fertilizer either to this luxury consumption or to the leachate channels.

We have very little information on the ability of our soils to fix soluble potash salts that may be applied in fertilizer. We have very little evidence showing that the potash supply of any of our soils has actually been increased by the heavy applications of potash that have sometimes been applied in fertilizer, in molasses or in the irrigation water. Hence, unlike phosphate, the supply of which we *can* build up, we are doubtful whether we have built up a potash reserve or even whether we can do so. Thus, to invest money for potash applications beyond the actual needs of the immediate crop would seem most uneconomical, and not to take full advantage of the natural supply of available soil potash would likewise appear to be wasteful.

In the case of potash fertilization then, we have only to consider the needs of the immediate crop when deciding upon our fertilizer policy. If our measures of available potash today indicate an ample supply, we can and should omit potash from the fertilizer applications; if they indicate a probable potash shortage we should be rather liberal with our potash application, for we recognize the full value of potash where sugar-making plants are concerned, and at the present low prices for potash, an expenditure of seven or eight dollars per acre should be able to guarantee us an adequate supply for a good sugar crop.

Nitrogen

As regards nitrogen, I have purposely left this discussion for the last, because it gives us a much more complicated problem to debate than either phosphate or potash. There is no argument with the fact that practically all of our cane crops must have supplementary nitrogen applications, but we do a great deal of guessing when we attempt to state how much supplementary nitrogen we should apply.

Except perhaps where there has been a drought, we do not know that nitrogen, non-utilized from an application to a previous cane crop, has remained in the soil and is available for the following crop. Where cane lands contain ample organic matter and receive a considerable amount of water, excess soluble nitrogen applications have a way of simply disappearing. Thus it appears problematical that we can build up any so-called nitrogen reserve in our soils, and as in the case of potash, our nitrogen problem becomes one of simply feeding the immediate cane crop with its requirements for maximum sugar production.

Our greatest concern, as we have attempted to decide how much nitrogen to apply, has been to avoid having an excessive amount of available nitrogen in the soil (especially close to harvest time) because of its detrimental effect, both directly and indirectly, on the cane quality.

As a rough guide only, we have made use of the amount of nitrogen as found by chemical analyses to be contained in a ton of cane, as the approximate amount that should be furnished the crop in the form of some nitrogen fertilizer salt. This has varied from about 2½ to 3½ pounds of nitrogen per ton of cane that we are expecting to harvest. Some of our previous studies have indicated that about 150 pounds of nitrogen were taken up by a fast-growing cane crop by the time that crop was 8 or 9 months old, and seldom have we provided our short crops with less than this amount of nitrogen in their fertilizer. After this "boom stage" period of growth, the further uptake of nitrogen does not exceed perhaps 5 to 10 pounds per month.

Amounts-of-nitrogen field experiments have indicated an optimum amount for one crop that has been excessive or insufficient on the following crop. It is my belief that such discrepancies are due chiefly to differences in the amounts of the available nitrogen in the soil resulting from the microbiological activity there. Whereas we have usually given some consideration to the amounts of available phosphate and potash in our soils when deciding what amounts of these minerals we would apply as fertilizer, we have never given the same consideration to the available nitrogen content of our soil. It is quite true that available soil nitrogen is an extremely complex and elusive material to determine, but an estimate of water-soluble forms of nitrogen alone should show sufficient qualitative differences in the available soil nitrogen content as of time of sampling, to make it possible for us to change a proposed application to fit the condition we find. I need only to cite an example or two to indicate the economies that could result from a more careful study of the specific nitrogen needs for our cane crops:

(1) If, after a crop had been supplied with 200 pounds of its scheduled 250 pounds of nitrogen, I were to suggest that another 100 pounds be given instead of the 50-pound balance as planned for the second season, I would immediately be challenged with a statement that such an application would ruin the juice, give less sugar, and increase the cost. Yet it is quite possible that at the very time the 50-pound second-season application is made, there may also be another 50 or 100 pounds of available nitrogen already present in the soil. In which event, we might withhold our proposed application to good advantage.

(2) We have tested soils in our Mitscherlich department, taken from fields immediately after harvest, that showed well over 200 pounds of available nitrogen per acre-foot; these fields had produced a good crop of cane from fertilizer applications that supplied 200 or more pounds of nitrogen. An economy might have been possible in these cases.

(3) Where heavy applications of filter cake and/or molasses have been made, a nitrogen economy is possible if soil conditions are favorable for the microbiological activity that will break down the protein nitrogen compounds therein. In general, we have failed to make allowance in our fertilizer applications for the nitrogen content of these mill by-products which carry approximately 10 pounds per ton. When

these mill by-product applications are heavy (10 to 20 tons per acre) the nitrogen contained therein may be quite a factor in affecting the ultimate sugar yield secured, especially where no cognizance is taken of the nitrogen content thereof that may be made available to the crop.

(4) With the advent of many new fast-growing cane varieties, with the vigor that such canes have brought from their "wilder" parents, we see the need for a very careful study of the nitrogen requirements for such canes. These fast starting, rapid first-season growers are quite different from the slower starting, fast second-season grower H 109, which has furnished us with most of our experience in determining optimum amounts of nitrogen, and we have just an indication that they are more economical nitrogen feeders. For instance, at Paauhau in 9 out of 12 AN tests, the maximum sugar from POJ 36 cane has come from nitrogen applications at or below 160 pounds, although larger amounts of nitrogen have given larger cane yields. At Wailuku, although two amounts-of-nitrogen tests on POJ 2878 cut at 15 months used 280 pounds of nitrogen to produce 57 tons of cane with 6.9 tons of sugar, and 75 tons of cane with 8.5 tons of sugar respectively, at Hakalau, 18 months old POJ 2878 gave a yield of 92½ tons of cane and 9½ tons of sugar with only 125 pounds of N. As yet we know very little about the optimum N requirements of POJ 2878, 28-1234, 31-1389, 26 Q 2873 and other fast growers. Hence it is important at this time to consider the installation of a considerable number of amounts-of-nitrogen tests on these canes, using in such tests four nitrogen variables at 50-pound differences, within a range that is definitely lower and higher than your present nitrogen practice: 100-150-200-250 pounds or 125-175-225-275 pounds, N.

I shall not discuss at this meeting the guides which have been given us as measures of soil nutrient differences. The field experiments, the Mitscherlich tests, and the various chemical tests of soils and juices are now familiar measures which I feel afford reliable estimates of the available plant food in our soils. With the advent of the new kit test for nitrogen which Dr. Hance has promised us, and the quick methods for analyzing cane juices, we shall be in a better position to determine soil differences and to use our fertilizers to a still better advantage and economy. There is a great deal of work ahead, however, before we shall be confident that we know how to interpret the results from the use of these new tools.

So far this discussion has concerned itself almost entirely with a determination of the need to apply various plant nutrients. The question of what form of fertilizer to use has quite generally resolved itself into a consideration of cost first, and theoretical suitability second. I shall not attempt to discuss this as a permanent policy at this time. In the case of our sugar crop a definite agricultural superiority of the various soluble potash and nitrogen carriers has rarely been established, and except on the more acid soil types, the water-soluble forms of phosphate are undoubtedly the most efficient, but of the several water-soluble phosphates, we have little proof of the superiority of one over any other.

We see little if any recent change in the time or in the method of applying fertilizer. If we are to reduce our total nitrogen application, we shall have a moot point to determine, i. e., whether to proportionally reduce the amount given at each application, or whether to drop out one of the applications entirely, and if the latter, then

which one. Our nitrogen "kit" test may be expected to help us to answer this question.

It is very evident that the plantation agriculturist is going to play a more important part in getting at the facts that will be used as the basis for this present trend of differential fertilization. He will need to develop a technique of field control that will enable him to be constantly on the lookout for changes in the status of the soil nutrients. With such a control, we may expect to eliminate still more of the guess work and develop a still more efficient and economic usage of commercial fertilizers.

An Improved Type of Hogpen

Submitted herewith are a set of photographs showing in detail the new concrete hogpens recently built by James Webster, manager, Pepeekeo Sugar Company.

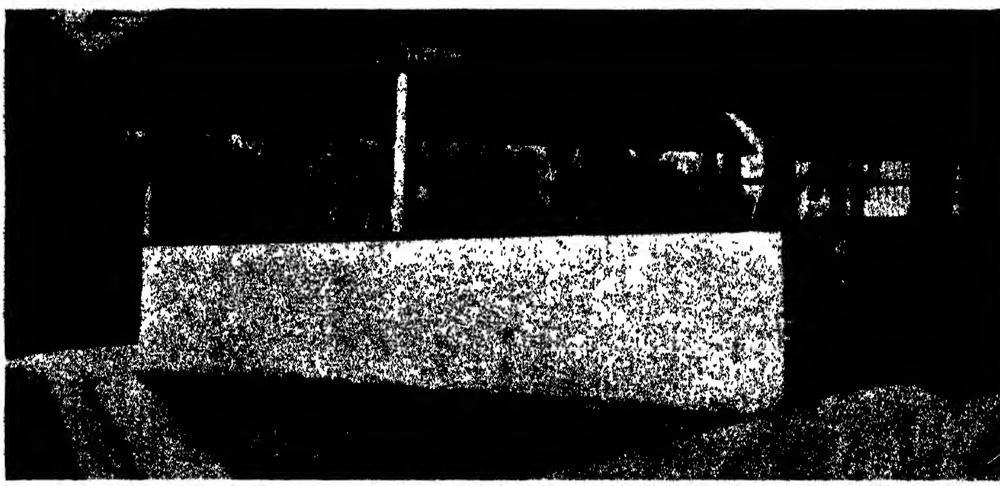
The photographs speak for themselves yet a few notes are in order. The building contains 22 pens, each 6 feet by 8 feet. The walls are 2.9 feet high. Each pen has a concrete floor with a slight slope to a corner where an outlet opens to a concrete drain. This drain empties into the sea over the cliff some fifty feet distant.

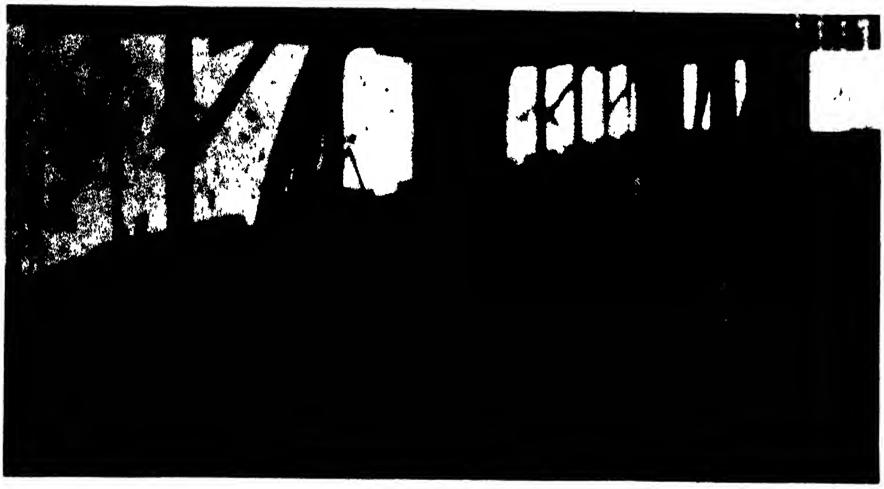
Water is piped through the building and a hose connection is made to serve each set of four pens. Thus the pens are flushed frequently and the building is kept clean.

The pens are rented to plantation employees at a low rate.

Acknowledgment is made to Mr. Webster for his courtesy in making the details of his project available to the industry.

S. M. M.





Plantation Fertilizer Practices

A CORRECTION

We issue herewith a corrected and more complete set of fertilizer schedules used at Oahu Sugar Company, Ltd., during 1934, which are intended to replace the schedules shown on page 54 of *The Hawaiian Planters' Record,* Vol. XXXIX, First Quarter, 1935.

D. S. J. and R. J. B.

List of Abbreviations Used

A.S.=Ammonium Sulfate.
N.S.=Nitrate of Soda.
A. P. "B."=Ammonium Phosphate "B."
A-14, A-22, A- 9 =Mixed Fertilizers

KEY

Kind of Fertilizer	N	P_2O_5	K_2O
	— %	— %	— %
—#P.A.	—#P.A.	—#P.A.	—#Per Acre

A-14
OAHU SUGAR CO.

N	7	6.0 Am. .5 Nit. .5 Organic
P_2O_5	20.5	3 Bone 17.5 Am.Phos & Super
K_2O	17	Sulfate & Nitrate
		44.5

A-22
OAHU SUGAR CO.

N	6	2.75 Am. 2.75 Nit. .50 Organic
P_2O_5	20	3.0 Bone 17.0 Am.Phos. & Super
K_2O	12	Sulfate & Nitrate
		38

A-9
OAHU SUGAR CO.

N	3	2.5 Am. .5 Organic
P_2O_5	15	3.0 Bone 12.0 Am.Phos. & Super
K_2O	28	Sulfate
		46

OAHU SUGAR CO.

I - LONG-PLANT FIELDS
A - Lowland fields - Spring started: Feb.-Mar.

①	A-14 / 500	7 / 35	20.5 / 102.5	17 / 85	FIRST SEASON: With Seed
②	A-14 / 600	7 / 42	20.5 / 123	17 / 102	8-12 Weeks after ①
③	A.S. / 350	20.5 / 71.7			May - June
④	N.S. / 500	15.5 / 77.5			SECOND SEASON:- Feb.-March
⑤	N.S. / 375	15.5 / 58.1			March - April
	Total	284.3	225.5	187	

I - LONG-PLANT FIELDS
B - Lowland fields - Summer Started: April - June

①	A-14 / 500	7 / 35	20.5 / 102.5	17 / 85	FIRST SEASON: With Seed
②	A-14 / 600	7 / 42	20.5 / 123	17 / 102	6-8 Weeks after ①
③	A.S. / 350	20.5 / 71.7			June - July
④	N.S. / 375	15.5 / 58.1			SECOND SEASON:- Feb.-March
⑤	N.S. / 500	15.5 / 77.5			March - April
	Total	284.3	225.5	187	

I - LONG-PLANT FIELDS
C - Middle-Belt fields - Spring started: March-April

①	A-14 / 500	7 / 35	20.5 / 102.5	17 / 85	FIRST SEASON: With seed
②	A-14 / 600	7 / 42	20.5 / 123	17 / 102	6-10 Weeks after ①
③	A.S. / 350	20.5 / 71.7			June - July
④	N.S. / 375	15.5 / 58.1			SECOND SEASON:- Feb.-March
⑤	N.S. / 500	15.5 / 77.5			March - April
	Total	284.3	225.5	187	

I - LONG-PLANT FIELDS
D - Upland fields - Early Summer started: April - June

①	A-22 / 500	6 / 30	20 / 100	12 / 60	FIRST SEASON: With seed
②	A-22 / 600	6 / 36	20 / 120	12 / 72	4-6 Weeks after ①
③	A.P."B" / 500	16 / 80	20 / 100		June - July
④	N.S. / 375	15.5 / 58.1			SECOND SEASON:- Feb.-March
⑤	N.S. / 500	15.5 / 77.5			March - April
	Total	281.6	320	132	

Note:- 400 lbs. of A.S. is substituted for A.P."B" when filter cake is plowed into the field.

I - LONG-PLANT FIELDS
E - Lowland, Coral-Type fields - Summer Started: May - July

①	A-9 / 400	3 / 12	15 / 60	28 / 112	FIRST SEASON: With Seed
②	A.S. / 200	20.5 / 41			Within 1 month
③	A-9 / 300	3 / 9	15 / 45	28 / 84	" " "
④	A.S. / 300	20.5 / 61.5			Not later than Oct.
⑤	N.S. / 500	15.5 / 77.5			SECOND SEASON: Feb. - March
⑥	N.S. / 375	15.5 / 58.1			March - April
	Total	259.1	105	196	

II - LONG-RATOON FIELDS
A - Lowland fields - Early Started: Nov.-Feb.

①	A-14 / 400	7 / 28	20.5 / 82	17 / 68	FIRST SEASON: Within 2 Weeks
②	A-14 / 700	7 / 49	20.5 / 143.5	17 / 119	8-12 Weeks after ①
③	A.S. / 350	20.5 / 71.7			May - June
④	N.S. / 500	15.5 / 77.5			SECOND SEASON: Feb. - March
⑤	N.S. / 375	15.5 / 58.1			March - April
	Total	284.3	225.5	187	

II - LONG-RATOON FIELDS
B - Lowland fields - Intermediate Started: March-May 15

①	A-14 / 400	7 / 28	20.5 / 82	17 / 68	FIRST SEASON Within 1 week
②	A-14 / 700	7 / 49	20.5 / 143.5	17 / 119	4-8 Weeks after ①
③	A.S. / 350	20.5 / 71.7			June - July
④	N.S. / 500	15.5 / 77.5			SECOND SEASON Feb. - March
⑤	N.S. / 375	15.5 / 58.1			March - April
	Total	284.3	225.5	187	

II - LONG-RATOON FIELDS
C - Lowland fields - Late started: after May 15

①	A-14 / 1100	7 / 77	20.5 / 225.5	17 / 187	FIRST SEASON Immediately
②	A.S. / 350	20.5 / 71.7			4-6 Weeks after ①
③	N.S. / 375	15.5 / 58.1			SECOND SEASON Feb. - March
④	N.S. / 500	15.5 / 77.5			March - April
	Total	284.3	225.5	187	

OAHU SUGAR CO.

I - Long-Ratoon Fields
D - Lowland, Coral-type fields

①	A-9 / 700	3 / 21	15 / 105	28 / 196	First Season: Within 2 weeks
②	A.S. / 300	20.5 / 61.5			4-6 Weeks after ①
③	A.S. / 350	20.5 / 71.7			May - June
④	N.S. / 375	15.5 / 58.1			Second Season: Feb.-March
⑤	N.S. / 375	15.5 / 58.1			March - April
	Total	270.4	105	196	

II - Long-Ratoon Fields
E - Middle-belt fields - Intermediate Started: Feb.-April

①	A-14 / 400	7 / 28	20.5 / 82	17 / 68	First Season: Within 1 week
②	A-14 / 700	7 / 49	20.5 / 143.5	17 / 119	4-8 Weeks after ①
③	A.S. / 350	20.7 / 71.7			June - July
④	N.S. / 375	15.5 / 58.1			Second Season: Feb.-March
⑤	N.S. / 500	15.5 / 77.5			March - April
	Total	284.3	225.5	187	

II - Long-Ratoon Fields
F - Middle-belt fields - Late started: May-June

①	A-14 / 1100	7 / 77	20.5 / 225.5	17 / 187	First Season: Immediately
②	A.S. / 350	20.5 / 71.7			2-4 Weeks after ①
③	N.S. / 375	15.5 / 58.1			Second Season: Feb.- March
④	N.S. / 500	15.5 / 77.5			March - April
	Total	284.3	225.5	187	

II - Long-Ratoon Fields
G - Upland fields - Intermediate started: Feb.-April
Low phosphate and high potash soil

①	A-22 / 500	6 / 30	20 / 100	12 / 60	First Season: Within 2 weeks
②	A-22 / 600	6 / 36	20 / 120	12 / 72	4-8 Weeks after ①
③	A.P."B" / 500	16 / 80	20 / 100		June - July
④	N.S. / 375	15.5 / 58.1			Second Season: Feb. - March
⑤	N.S. / 500	15.5 / 77.5			March - April
	Total	281.6	320	132	

II - Long-Ratoon Fields
H - Upland fields - Late started: May - June
Low phosphate and high potash soil

①	A-22 / 1100	6 / 66	20 / 220	12 / 132	First Season: Immediately
②	A.P."B" / 500	16 / 80	20 / 100		2-4 Weeks after ①
③	N.S. / 375	15.5 / 58.1			Second Season: Feb.- March
④	N.S. / 500	15.5 / 77.5			March - April
	Total	281.6	320	132	

II - Long-Ratoon Fields

Note:- Fields under Groups A, B, C, E and F. Poor spots and pali sections found in the fields of the above groups receive an additional 200 pounds of A-14 fertilizer per acre.

Fields with low potash in the soil receive a potassic-nitrogenous fertilizer in place of Ammonium Sulfate to give the same amount of nitrogen.

III - Short-Ratoon Fields
A - Lowland & Middle-belt Fields - Early Started: Nov.-Mar.

①	A-14 / 400	7 / 28	20.5 / 82	17 / 68	First Season: Within 2 weeks
②	A.S. / 350	20.5 / 71.7			2-8 Weeks after ①
③	A-14 / 700	7 / 49	20.5 / 143.5	17 / 119	3-10 " " ②
④	N.S. / 375	15.5 / 58.1			8-10 " " ③
⑤	N.S. / 375	15.5 / 58.1			4-6 " " ④
	Total	264.9	225.5	187	

III - Short-Ratoon Fields
B - Lowland, Coral-type fields - Intermediate & Late Started

①	A-9 / 700	3 / 21	15 / 105	28 / 196	First Season: Immediately
②	A.S. / 300	20.5 / 61.5			Applications are spaced at suitable intervals
③	A.S. / 300	20.5 / 61.5			
④	A.S. / 300	20.5 / 61.5			
⑤	N.S. / 375	15.5 / 58.1			Not later than Oct.
	Total	263.6	105	196	

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
DECEMBER 17, 1934, TO MARCH 13, 1935.

Date	Per Pound	Per Ton	Remarks
Dec. 17, 1934	2.60¢	$52.00	Cubas.
Jan. 2, 1935	2.72	54.40	Cubas.
" 3	2.77	55.40	Puerto Ricos.
" 4	2.822	56.44	Puerto Ricos, 2.80, 2.81, 2.83, 2.85; Cubas, 2.82.
" 5	2.83	56.60	Cubas.
" 7	2.84	56.80	Philippines, 2.83, 2.85; Puerto Ricos, 2.85.
" 8	2.83	56.60	Philippines.
" 9	2.81	56.20	Philippines.
" 10	2.80	56.00	Puerto Ricos, Philippines.
" 11	2.7833	55.67	Philippines, 2.77, 2.78, 2.80; Puerto Ricos, 2.78.
" 12	2.77	55.40	Philippines.
" 14	2.78	55.60	Philippines, 2.77, 2.79.
" 15	2.80	56.00	Philippines.
" 17	2.785	55.70	Philippines, 2.80; Cubas, 2.77.
" 18	2.80	56.00	Puerto Ricos.
" 21	2.78	55.60	Cubas.
" 22	2.80	56.00	Cubas, Puerto Ricos, Philippines.
" 23	2.835	56.70	Philippines, 2.82, 2.85; Puerto Ricos, 2.82.
" 24	2.81	56.20	Puerto Ricos, 2.82; Cubas, 2.80.
" 28	2.79	55.80	Puerto Ricos, 2.78, 2.80; Cubas, 2.78.
" 29	2.77	55.40	Cubas, 2.76, 2.78; Puerto Ricos, 2.76.
" 31	2.78	55.60	Puerto Ricos.
Feb. 1	2.80	56.00	Puerto Ricos, Philippines.
" 4	2.82	56.40	Puerto Ricos.
" 5	2.85	57.00	Puerto Ricos, Philippines, Cubas.
" 7	2.86	57.20	Philippines.
" 8	2.85	57.00	Puerto Ricos.
" 14	2.90	58.00	Philippines, Puerto Ricos.
" 21	2.945	58.90	Cubas, 2.94; Philippines, 2.95; Puerto Ricos, 2.95.
" 23	2.97	59.40	Cubas.
" 26	3.00	60.00	Cubas.
" 27	2.985	59.70	Cubas, 3.00; Puerto Ricos, 2.97.
" 28	2.97	59.40	Puerto Ricos.
Mar. 5	3.00	60.00	Philippines.
" 6	2.99	59.80	Philippines, 2.98; Puerto Ricos, 2.98, 3.00.
" 8	3.00	60.00	Puerto Ricos.
" 11	3.05	61.00	Puerto Ricos.
" 13	3.00	60.00	Cubas, Puerto Ricos.

THE HAWAIIAN PLANTERS' RECORD

Vol. XXXIX THIRD QUARTER, 1935 No. 3

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

The Giant Moth Borer:

The most dreaded of all sugar cane insect pests entered Hawaii alive in April of the present year and was discovered and destroyed three months later. A description of the insect and the circumstances involved in its introduction are given together with a discussion of the damage caused by it to sugar cane in other countries.

Emergency Conservation Work in Hawaii:

The nature and extent of the Conservation work being carried on quietly but effectively throughout the Territory is well illustrated by the two quarterly reports of L. W. Bryan, which we are printing in this number of the Record with the consent of James W. Lloyd, Business Administrator, Emergency Conservation Work for Hawaii.

Studies of Enzyme Action in Sugar Cane:

This is a non-technical account of some of the more important characteristics of enzymes, those active agents which enable plants and animals to carry on the chemical changes essential to life at the temperature of the living plant or animal. The paper is offered as an introduction to the enzyme studies now being conducted at the Experiment Station.

Plant Food Values in Molasses and Filter Cake:

A progress report is made on the results that have been secured from a series of pot tests, wherein an attempt is being made to evaluate the plant food that is carried by molasses and filter cake. The results give rather definite indications that the potash and phosphate contained in these two by-product materials have a crop-producing power that is fully equal to or better than equivalent amounts of the nutrients from commercial fertilizer.

The evaluation of their nitrogen content is somewhat complicated. There is undoubtedly some loss of nitrogen to the growing crop from the total available

supply, when these highly carbonaceous materials are used. No attempt is made to explain this loss, although it may probably be associated with the differences between the nitrogen-carbon ratios of the soils and of the two by-products that were applied thereto.

Two Sugar Cane Pests in Guatemala:

An interesting account is given of two sugar cane pests which F. A. Bianchi studied while in Guatemala. These pests, the one a large stem-boring beetle, the other a root-feeding bug, were found capable of doing serious damage to sugar cane.

Sources of Nitrogen:

The probable influence which the soil reaction has upon the comparative efficiencies of several sources of nitrogen was quite definitely shown when these several materials were applied in solution in water to various soils which were potted and planted with Sudan grass. Anhydrous ammonia was less effective than ammonium sulphate on the neutral and slightly alkaline soils but this efficiency decreased where the slightly acid and acid soil type were concerned.

Giant Sugar Cane Moth Borer Intercepted in Honolulu

By C. E. Pemberton

On April 12, 1935, a Honolulu resident imported from the Panama Canal Zone 12 corms of the ornamental plants *Heliconia angustifolia* and *Heliconia bihai*, there being six plants of each species. This introduction was in compliance with the Territorial Plant Quarantine regulations, an application for the importation having been duly filed and granted. The material was fumigated by a plant quarantine officer and, in the ordinary course of events, would have been immediately released to the importer. Fortunately, however, Dr. H. L. Lyon was consulted by the Chief Plant Inspector respecting the advisability of releasing this material after fumigation. Dr. Lyon was of the opinion that its immediate release would be unsafe in spite of the fumigation, because of the fleshy nature of the corms and the uncertainty of penetration by the fumigation gases into the interior, where borers or other insects might be concealed. The importer agreed to permit the retention of the plants in a tightly screened quarantine house in Dr. Lyon's care in order that they might be kept under observation for some time. This was done.

On July 16, 1935, Dr. Lyon observed a large handsomely colored moth flying about in the quarantine house. This was captured, killed and later identified by O. H. Swezey as a form of *Castnia licus* Drury, the dreaded Giant Sugar Cane Moth Borer of tropical America. Close examination of the plant material showed where the large larva matured in the root stalk of one of the *Heliconia angustifolia* plants and formed a pupa from which the moth had finally emerged.

We have here a case in which the worst known pest of sugar cane reached our shores alive and in perfect condition, after having passed through the regular procedure of fumigation administered to all imported plants from most outside localities by our Plant Quarantine Service. This pest was only prevented from escaping into the open through a fortunate combination of circumstances. Present quarantine methods of fumigation and release of plant material to the importing public are clearly shown to be inadequate for our protection. If fumigation will not render imported plant material safe, such material should not be permitted entry into the Territory until facilities for its safe treatment and handling are provided.

Should the Giant Sugar Cane Moth Borer become established in Hawaii, millions of dollars to the sugar industry would be annually lost. No effective parasites are known on it. Certain birds in Trinidad and Guiana are the most useful enemies on record and are encouraged to live in the cane fields of those countries through the provision of bamboo bird perches throughout the cane fields. This moth borer is so bad in some regions that rats, which eat out the larvae from the stalks, are said to be protected on one estate. An active drive was even made against the mongoose in order that the rats would have better opportunity to increase in the cane fields. Flooding the fields for 72 hours has been said to be an effective remedy in British Guiana, where the cane is all on flat, low land surrounded by water. There are few spots in Hawaii, if any, where this could be done. The only other method of control

so far known is the capture of the adult moths with butterfly nets and the digging out of the large larvae from the stools after harvest, which is slow and very expensive.

The larva of the giant moth borer, when mature, may measure four inches in length and one-half inch in diameter. The moth spreads from three to four inches across the wings. A single larva becomes so large and powerful when full grown that the cane it occupies may be completely ruined, from the milling standpoint. Shortly before pupating the larva bores down through the stalk into the underground portion of the stool, where it pupates. In consequence of this, few of the well-grown larvae are killed in the process of harvesting, since they are not carried to the mill in the cane but are left behind in the stool to hatch into moths and carry on the destruction.

Like many pests of the sugar cane plant, the giant moth borer infests other plants besides cane, which include at least the two species of Heliconia above mentioned, bananas and plantains, young coconut palms, another palm *Oreodoxa oleracea* in Trinidad, and rarely in at least one species of grass on the same island, according to Myers (1). The danger of importing new pests of sugar cane in other plants is well demonstrated in the case under discussion.

The following extracts taken from the published reports of three entomologists who have studied the giant moth borer, will give a fair picture of the importance of this pest in the cane countries where it occurs.

Myers (1) states that in Trinidad:

. . . it is now widespread and increasing in destructive activity. It is possible to find carts of ''farmer's'' canes 90 per cent. of which have been bored by this insect. And one boring by such a large larva is more destructive than many by *Diatraea*. In Trinidad cane-fields, save an infinitesimal minority near the Caroni River, flooding is quite impracticable, and the only method of direct control is hand-collecting of the larvae from young canes and from cut stools, coupled with the capture of the adult moths.

In this way, on one estate (Skinner, 1929), 356,000 moths were destroyed between July 1927 and January 1928. This was followed by a campaign against the larvae, of which 1,667,357 were paid for between January and November, 1928. . . .

There is a significant difference between the giant-borer and the small borers *(Diatraea)*, for whereas the latter, when the canes are cut, are carried, in the vast majority, into the mill and destroyed when the canes are crushed, the former are left in the stool, where they may easily continue their development and emerge as moths.

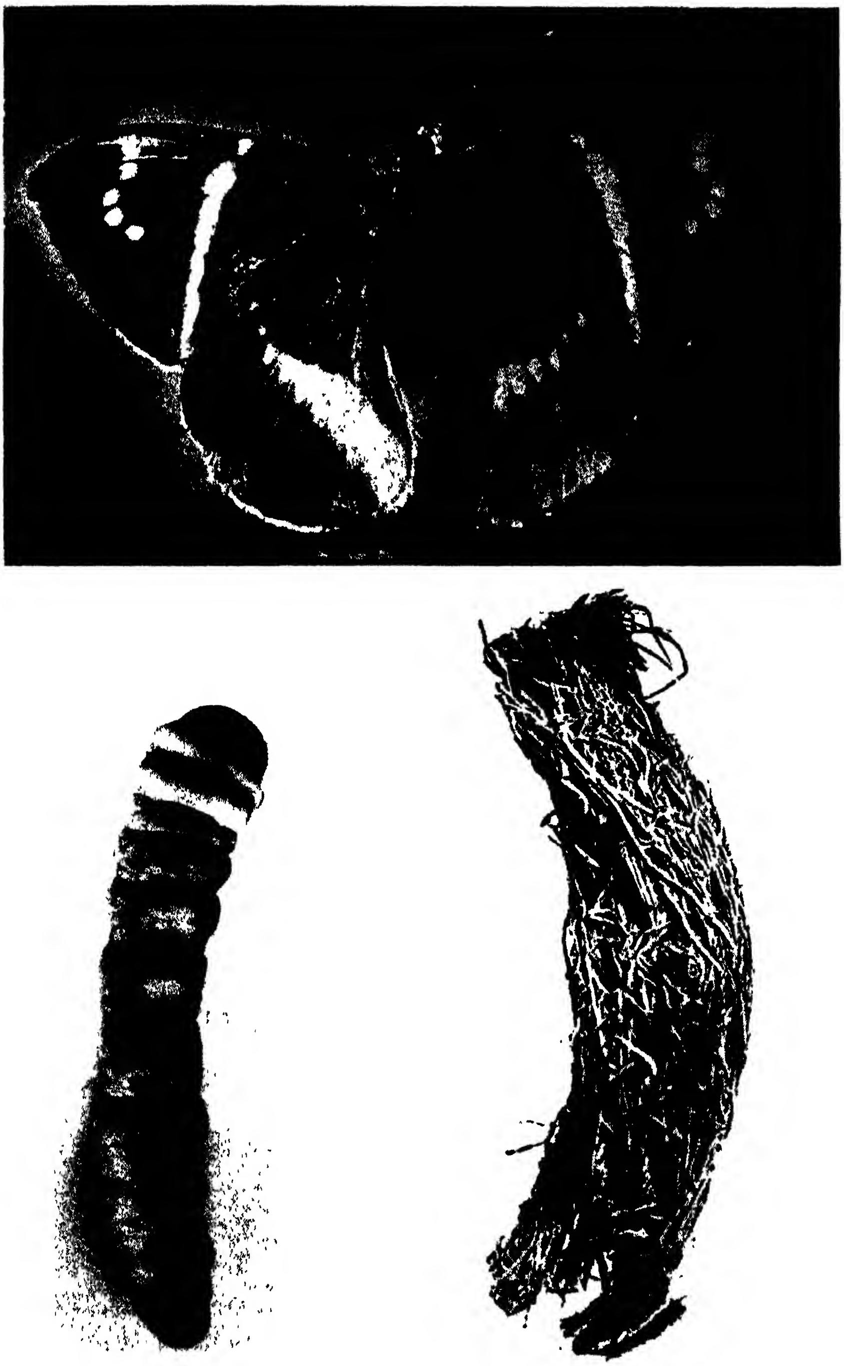
Skinner (2) remarks that:

Unlike the small moth borers, *Diatraea* spp., which cause enormous losses [in many countries] *Castnia licus* is confined to Trinidad, British Guiana and some other parts of South America where its depredations may be very severe. A severe outbreak of this borer in Demerara was investigated by Quelch (4) and his conclusions were published in 1910. In the same year, Urich (5) called attention to *Castnia licus* as a possible future pest of sugar cane, but it is only during the past two or three years that it has increased in the southern part of Trinidad to major pest proportions.

In 1927-28, this pest increased to an alarming extent in the Naparima district of Trinidad and the losses resulting exceeded those due to *Diatraea* and to the Frog-hopper. . . .

Fully grown larvae (and also adult moths) vary considerably in size; when fed on large succulent cane, they may measure as much as four inches in length and ½ inch in diameter in front, but specimens of half this size are encountered. They are voracious feeders, tearing the cane fibres with their powerful mandibles, expressing the juice which they swallow and rejecting the fibre which they work down behind them, large quantities . . . being always found in their burrows. . . .

In badly infested areas, the damage caused by *Castnia licus* is enormous. Parts of fields have been seen in which practically every stool has been attacked and with 50 per cent. or more of the cane bored. A single *Castnia* larva can destroy as much as 1½ to 2 feet of canes apart



Giant sugar cane moth borer showing adult moth, larva and cocoon, all natural size.

from boring down in the root stock. In addition to the loss of weight due to boring, the unbored portion sometimes dries up and is lost or at best deteriorates very considerably in purity and

sucrose content, whilst the glucose ratio is greatly increased. The boring of the root stock weakens the stool greatly, completely destroying it in some cases, and invariably reducing its ratooning powers. Enormous numbers of young shoots and suckers are converted into "dead-hearts," which means that they never produce cane. It is probably not an exaggeration to say that, in badly attacked fields, the loss may easily reach 25 per cent. of the crop.

Wolcott (3), in his book on the economic entomology of the West Indies, writes as follows regarding Castnia damage to sugar cane:

It may well be imagined how serious is the injury that even one caterpillar can cause. When the cane is young, one individual will often kill several stalks, so that one can readily notice the injury looking over a cane-field. Older cane is not killed by *Castnia* caterpillars, for the larva eats only the sweet pithy inside of the cane, so that growth at the top is not appreciably checked. It is only when the cane is cut that one can accurately determine the extent of the injury, as then the large holes in the stubble are most noticeable; or looking at the cane in the cane cars, the number of hollow bases gives an index of infestation.

The intercepted moth and cocoon from which it hatched are shown in the accompanying illustration together with a larva collected by Dr. F. X. Williams in South America several years ago. The photographs, by Wm. Twigg-Smith, show the specimens in natural size.

Literature Cited

(1) Myers, J. G., 1931. A preliminary report on an investigation into the biological control of West Indian insect pests. Publication of the Empire Marketing Board, No. 42, pp. 102-105.

(2) Skinner, H. Martyn, 1930. The giant moth borer of sugar-cane. Supplement to Tropical Agriculture, January 1930, 8 pages, 1 plate, 2 figures.

(3) Wolcott, George N., 1933. An economic entomology of the West Indies. The Entomological Society of Puerto Rico, San Juan, p. 144.

(4) Quelch, John J., 1910. Report on the giant moth borer. Georgetown, Demerara. The Argosy Co., Ltd.

(5) Urich, F. W., 1910. The cane sucker *(Castnia licus)*. Bulletin of the Department of Agriculture, Trinidad, Vol. IX, p. 43.

Emergency Conservation Work
Associate Forester's Narrative Report
Island of Hawaii
For October, November and December, 1934*

General

Our second enrollment period began on October 1, with 59 enrolled men, 7 foremen and 1 clerk. All of these enrolled men continue to live at home, furnish their own subsistence, and are paid at the rate of $2.00 per day, five days per week. Actually, some of these men spend part of their time in temporary camps in order to be close to their work. These camps are furnished them gratis and such equipment as has been needed has been purchased with ECW funds. The men purchase their own food supplies and do their own cooking. This system has worked out to advantage on some of our projects that are too far away to be economically handled from the enrollees' homes.

The average age of our enrolled men is 26 years and they are divided into racial groups as follows:

Japanese	19
Portuguese	18
Caucasian-Hawaiian	9
Hawaiian	5
Caucasian-Chinese	2
Chinese	2
Korean	1
Hawaiian-Chinese	1
Korean-Hawaiian	1
Caucasian	1
Total	59

During the first quarter of our second enrollment period we have lost 9 enrolled men through discharge and have had 3 accidents requiring medical attention. Eighty-four per cent of our first enrollment period men were re-enrolled to serve an additional six months period.

Technical supervision and local administration of the work have been continued under the direction of local officials of the Territorial Division of Forestry.

Equipment

All of our ECW equipment has been maintained in good condition, particular care being taken with trucks and other cars. No new heavy equipment has been

* We are indebted to James W. Lloyd, Business Administrator, Emergency Conservation Work for Hawaii, for the privilege of printing this report by L. W. Bryan.

needed since the beginning of ECW. New minor equipment has been secured as needed.

Work Accomplished

Our program of work for this island is divided into the following:

- (a) Nursery Work
- (b) Planting, Maintenance
- (c) Planting, Forestation
- (d) Truck Trail Construction
- (e) Horse Trail Construction
- (f) Fence Building
- (g) Firebreak
- (h) Elimination of Useless Range Stock
- (i) Structures

(a) Nursery Work:

In addition to supplying trees needed for our ECW program requirements, we have been able to maintain a surplus which has been distributed to homesteaders, farmers and others for general planting. On Arbor Day, November 9, a total of 11,467 trees, shrubs and vines were given away from the Hilo Nursery in accordance with our usual custom. A total of 100,414 trees have been distributed during the period covered by this report.

(b) Planting, Maintenance:

In Hawaii, with our heavy rainfall and twelve months growing season, considerable follow-up work is necessary in order to insure our young trees against being choked out by rapid-growing grass and other weeds. All young trees planted must be gone over and cleaned around at least once, frequently twice, and sometimes three cleanings are found necessary, depending upon the species of tree used and the type of weeds found growing in a given locality.

During the past three months we have cleaned around 174 acres of trees which were planted out during our first enrollment period. In laying plans for this work, at the beginning of this period, we estimated that there would be a ten per cent mortality in trees planted. Actually our mortality has fallen below this figure for out of the 174 acres cleaned we have been obliged to replant only 15.63 acres or nine per cent.

(c) Planting, Forestation:

Our program calls for the planting of trees on 200 acres of land located within four different forest reserves in ten different localities.

The following tabulation shows what has been accomplished to date:

Hilo Forest Reserve

Land of Piihonua:		
Eucalyptus microcorys	788	
Eucalyptus robusta	15,566	
Eucalyptus saligna	459	
	16,813 trees	38.65 acres
Land of Laupahoehoe:		
Eucalyptus resinifera	1,970	
Thuja occidentalis	44	
	2,014 trees	4.63 acres
Total, Hilo Reserve...........	18,827 trees	43.28 acres

Kohala Forest Reserve

Land of Puukapu:		
Eucalyptus resinifera	1,281	
Eucalyptus rostrata	2,581	
	3,862 trees	8.88 acres
Land of Lanikepu:		
Eucalyptus robusta	1,341 trees	3.08 acres
Total, Kohala Reserve.........	5,203 trees	11.96 acres

Waiaha Spring Forest Reserve

Land of Waiaha:		
Eucalyptus robusta	2,358 trees	5.43 acres
Total, Waiaha Spring Reserve..	2,358 trees	5.43 acres

Hamakua Forest Reserve

Land of Honokaia:		
Eucalyptus paniculata	332	
Eucalyptus robusta	1,008	
Eucalyptus rostrata	46	
Eucalyptus siderophloia	86	
	1,472 trees	3.38 acres
Land of Hoea-Kaao:		
Casuarina glauca	53	
Eucalyptus saligna	300	
	353 trees	.81 acre

Land of Kaohe:		
Eucalyptus microcorys	1,608	
Eucalyptus paniculata	2,840	
Eucalyptus resinifera	554	
Eucalyptus rostrata	5,018	
	10,020 trees	23.03 acres
Total, Hamakua Reserve	11,845 trees	27.22 acres
Total, Island of Hawaii	38,233 trees	87.89 acres

(*d*) *Truck Trail Construction:*

Our program provides for construction of two truck trails, one of 6.00 miles in length along part of the upper boundary of the Hilo Reserve and one, 2.50 miles long, within the Nanawale Reserve. Work on these trails has gone along satisfactorily and the following has been completed:

Keanakolu-Hopowai Truck Trail	2.88 miles
Nanawale Truck Trail	.25 "
Total	3.13 miles

In addition to these two truck trails it was found necessary to construct a truck trail in order to reach the land of Kaohe within the Hamakua Reserve. This was necessary in order to eliminate mule packing of trees and fence materials in this section. The total length of this truck trail is 1.75 miles and with it in use we have been able to truck in all of our trees, fence materials and labor. This makes a total of 4.88 miles of truck trails completed.

(*e*) *Horse Trail Construction:*

In the Kohala Reserve, Land of Pololu, our program calls for the rebuilding of 1.20 miles of horse trail. To date we have completed 0.78 mile of this trail or over one-half of this project. This trail follows easy grades, is six feet wide, and when finished will connect the lower government trail with the upper ditch trail.

(*f*) *Fence Building:*

Our original program provided for the construction of two new fences, one in the land of Puukapu, Kohala Reserve, and one in the land of Kaohe, Hamakua Reserve, a total length of 2.05 miles. In addition to this it was found necessary to build an additional 1.08 miles of fence in order to provide enclosed areas around our new shelter houses on Mauna Kea for work animals being used by our men engaged in Elimination of Useless Range Stock in this section.

The following table shows what has been done to date:

Puukapu Fence	0.84 mile
Kaohe Fence	0.64 "
Mauna Kea Fences	1.08 miles
Total	2.56 miles

The Puukapu fence is being constructed throughout with No. 1047 galvanized stock wire and redwood posts. The Kaohe fence is being made partly with this same material and partly with ohia posts and 5 strands of No. 6 smooth, galvanized wire. The Mauna Kea fences are constructed of No. 1155 stock wire and the posts were cut from local mamani trees. Suitable gates have been installed where needed.

(*g*) *Firebreak:*

This project, as planned, called for the clearing out of an old Hawaiian trail leading from the National Guard Rifle Range to the Keaau Boundary across part of the land of Waiakea. After the work was started we found that it would save time to be able to drive our trucks in on this firebreak. This required a little extra work but it has been well worth the effort as we can now take our trucks with labor and tools right in as far as the work has progressed. This will be of great advantage in case of fire in this section. To date we have completed 2.58 of the proposed 4.50 miles.

(*h*) *Elimination of Useless Range Stock:*

This problem is a serious one and one that will require much time and effort to bring to a successful termination. Much preliminary work is necessary before we can safely venture to attempt the poisoning of these animals on a large scale. At present we are experimenting to find a suitable bait to which we can later add poison.

On this Island there are many thousands of wild goats, sheep and pigs and they constitute a serious menace to sections of our forests. Within the Mauna Kea Forest Reserve (an area of 68,272 acres) the wild sheep and goats are so numerous that it is impossible to find any natural reproduction of the predominating tree growth, mamani *(Sophora chrysophylla)*. These animals are very fond of this tree and if they are not eliminated, or greatly reduced in numbers, it will be only a matter of time before this section will be completely denuded.

To date we have confined our activities to the shooting of these pests. At the beginning of the program this work was delayed by the Finance Officer's refusal to pay for arms and ammunition. This matter was finally settled and sufficient ammunition and arms have been ordered to carry on this part of the work. During the past three months 1,139 of these animals have been killed.

(*i*) *Structures:*

Our approved program did not specify any particular number of structures but in order to provide places for our men to stay while engaged in the Elimination of Useless Range Stock on Mauna Kea, it was found necessary to construct three small shelter houses at different points on the mountain. These buildings are all alike; 12 x 16 feet, constructed of T&G, with galvanized iron roof, 2,000-gallon water tank, built-in bunks, iron sink, small stove and necessary cooking and eating utensils to accommodate six men. They are located on the mountain at about 8,000 feet elevation and are working out very well in practice, and will always be of value in our regular routine forest work. Around each shelter we have fenced off an area in which to pasture such work animals as are necessary to carry on this work.

Photographs

A number of photographs are included showing some of the work being done.

L. W. Bryan, Associate Forester.

Plant benches with young forest trees at the Hilo Nursery.

Puu Kahinahina shelter for use of men engaged in elimination of wild sheep, Mauna Kea Reserve.

Widening out old Hawaiian trail, Nanawale truck trail.

Working on Nanawale truck trail.

Pulling guava stumps, Waiakea firebreak.

Preparing holes for tree planting, land of Puukapu, Kohala Reserve.

Emergency Conservation Work
Associate Forester's Narrative Report
Island of Hawaii
For January, February and March, 1935*

General

This report covers the last quarter of our first year's work under ECW on Hawaii. During this quarter we have completed practically all of our contemplated projects and in addition have accomplished more along certain lines than was at first expected. All of our men continue to live at home, work 5 days per week and are paid at the rate of $2.00 per day for juniors, and $2.50 per day for experienced men. At the close of the quarter we had the following:

110 Junior Enrolled Men
8 Experienced Enrolled Men
8 Foremen
1 Clerk

and in addition, three foremen and one project superintendent were employed during the latter part of the quarter to assist in getting ready for our new program which has been approved for this Island.

During this quarter we have expended a total of 9,343 man-days on all of our projects; we have lost 8 enrolled men through discharge; have had 5 accidents requiring medical attention and have lost 13 man-days due to these accidents.

All technical supervision and local administration have been cared for by local officials of the Territorial Division of Forestry.

Considerable work has been done on our new set-up for the fifth enrollment period. Plans for our camps have been prepared and actual work on their construction has been started. Wire for our fence as well as other equipment has been ordered. Due to failure of early passage of the relief bill we were not able to start construction of our water tanks at the new Keanakolu Camp. This delay may hold up the work in this section for several months for we must first secure rain water in our tanks before this camp can be utilized. Unfortunately the winter rains came while this important work was suspended.

Equipment

All of our equipment has been maintained in good condition. Our trucks and station wagons have been run for a total of 76,274 miles since we first secured them about one year ago. They are still in first class shape and good for many more miles.

* We are indebted to James W. Lloyd, Business Administrator, Emergency Conservation Work for Hawaii, for the privilege of printing this report by L. W. Bryan.

Work Accomplished

Our program of work for this Island is divided into the following sections:

(a) Firebreak
(b) Truck Trail
(c) Horse Trail
(d) Other Structures
(e) Fence, other than range
(f) Planting, Forestation
(g) Planting, Maintenance
(h) Nursery
(i) Elimination of Useless Range Stock.

(*a*) *Firebreak:*

The original estimated distance of this project was 4.50 miles. Actually we found, upon completion, that it was only 3.70 miles. During the first quarter we completed 2.58 miles and the remainder of 1.12 was completed during the period under consideration. This Firebreak, as constructed, enables us to traverse its entire length with our trucks, being a decided advantage in case of fire.

(*b*) *Truck Trails:*

Our original program called for the construction of 8.50 miles of truck trails during the fourth enrollment period. On February 7, a supplemental program was approved for 19.50 miles of truck trails on Mauna Kea making a total of 28.00 miles. The following tabulation shows what has been accomplished:

Keanakolu-Hopowai Truck Trail	7.00	miles
Nanawale Truck Trail	2.90	"
Kaohe Truck Trail	1.75	"
Umikoa-Keanakolu Truck Trail	9.00	"
Hanaipoe-Puu Mali Truck Trail	2.90	"
Kalaieha-Puu Hookomo Truck Trail	1.65	"
Laumaia-Puu Kahinahina Truck Trail	3.02	"
Total	28.22	miles

With the exception of the Nanawale Truck Trail all of the above were comparatively easy to construct. The Nanawale Truck Trail was much more difficult and required much more time than was first contemplated.

(*c*) *Horse Trail:*

Our approved program provided for the construction of 1.20 miles of horse trail in the land of Pololu, Kohala Forest Reserve. This work went along much faster than was expected and as a result we were able to extend this trail and complete it for a total distance of 2.32 miles.

(*d*) *Other Structures:*

These structures, three in number, were constructed as a part of our Elimination of Useless Range Stock Program and were completed during the first part of the enrollment period and reported in our last Narrative Report. They have worked out very well in practice making comfortable shelters for our men who are engaged in this work at high elevations on Mauna Kea.

(*e*) *Fence, other than range:*

A total of 3.24 miles of new fence has been constructed during this enrollment period as follows:

Puukapu Fence	1.14	miles
Kaohe Fence	.91	"
Mauna Kea Fences	1.19	"
Total	3.24	miles

(*f*) *Planting, Forestation:*

Our program calls for the planting out of 87,775 trees on 202 acres of land in ten different locations on four different forest reserves. Trees are planted about 10 x 10 feet or 435 trees to the acre. On some of the reserves we have planted less than we expected while on others we have planted more than our program calls for.

During the entire period there have been planted 89,187 trees on 205 acres of land as follows:

Hilo Forest Reserve

Land of Kaiwiki 3rd:			
Eucalyptus robusta	393	trees	.90 acre
Land of Laupahoehoe:			
Eucalyptus resinifera	1,970		
Thuja occidentalis	44		
	2,014	trees	4.63 acres
Land of Piihonua:			
Eucalyptus microcorys	788		
Eucalyptus robusta	15,566		
Eucalyptus saligna	459		
	16,813	trees	38.65 acres
Total, Hilo Reserve	19,220	trees	44.18 acres

Kohala Forest Reserve

Land of Puukapu:			
Casuarina glauca	10,035		
Eucalyptus resinifera	1,281		
Eucalyptus robusta	19,896		
Eucalyptus rostrata	2,581		
		33,793 trees	77.69 acres
Land of Lanikepu:			
Eucalyptus robusta		1,341 trees	3.08 acres
Total, Kohala Reserve		35,134 trees	80.77 acres

Hamakua Forest Reserve

Land of Honokaia:			
Casuarina glauca	2,540		
Eucalyptus paniculata	725		
Eucalyptus robusta	1,047		
Eucalyptus rostrata	46		
Eucalyptus siderophloia	86		
		4,444 trees	10.22 acres
Land of Kaohe:			
Eucalyptus microcorys	1,608		
Eucalyptus paniculata	2,840		
Eucalyptus resinifera	2,288		
Eucalyptus rostrata	10,008		
Grevillea robusta	5,407		
		22,151 trees	50.91 acres
Land of Hoea-Kaao:			
Casuarina glauca	1,956		
Eucalyptus saligna	300		
		2,256 trees	5.18 acres
Total, Hamakua Reserve		28,851 trees	66.31 acres

Waiaha Spring Forest Reserve

Land of Waiaha:			
Eucalyptus robusta		5,982 trees	13.76 acres
Total, Waiaha Spring Reserve		5,982 trees	13.76 acres
Total, Island of Hawaii		89,187 trees	205.02 acres

(*g*) *Planting, Maintenance:*

This is one of the most important phases of our work, for it is only by following up our plantings and keeping them free from weeds and grass, that we can be assured of a good stand of trees later.

During the past six months we have cleared around 165,735 trees on 381 acres of land. We originally estimated that there would be about ten per cent mortality. Actually we were obliged to re-plant only 32 acres or 8 per cent.

(*h*) *Nursery:*

The original project called for 786 man-days to be spent on nursery work. On February 7, an additional 500 man-days was approved as a supplemental project making a total of 1,286 man-days for this work. This additional labor was required in order to start the work of preparing additional planting material to be used during the fifth enrollment period. As a result of this additional 500 man-days we have been able to start a great many more trees which will be available for our planting during the first part of the next enrollment period.

During the six months period we have produced and distributed a total of 168,208 trees from the Hilo Nursery. We have also taken care of the surrounding grounds; gathered what seed we could locally; rebuilt 89 of the plant benches, using old iron rails with concrete foundations; constructed 10 new plant benches; constructed over 3,000 new plant flats; as well as other routine work.

(*i*) *Elimination of Useless Range Stock:*

Our activities along these lines have been extended to three different reserves and to shooting and driving wild goats, hogs and sheep. To date no practical method of poisoning these animals has been found fully successful. During the fifth enrollment period we plan to do extensive fence work on Mauna Kea which will greatly assist in controlling the thousands of wild sheep which are so abundant in this reserve. These animals are so plentiful that for a number of years there has been no natural reproduction of the predominating tree growth (*Sophora chrysophylla*) in this region, except in a few small sections that have been fenced so as to exclude all stock. By eliminating these pests we can expect a new forest growth to come back naturally.

During this enrollment period we have killed a total of 4,336 animals as shown in the following tabulation:

	Sheep	Pigs	Goats	Total
Mauna Kea Reserve.......	2554	88	7	2649
South Kona Reserve.......	....	3	1515	1518
Honuaula Reserve	15	9	145	169
Totals................	2569	100	1667	4336

Photographs

A number of photographs are included showing some of our work accomplished or under way.

L. W. Bryan, Associate Forester.

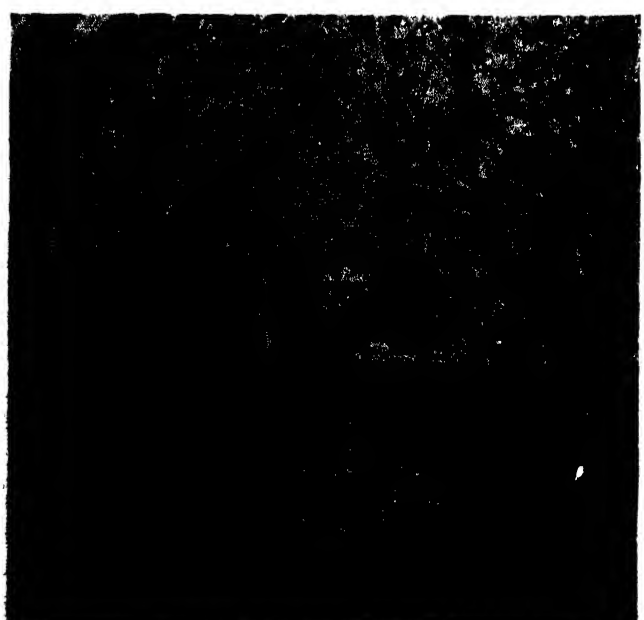
Clearing line for tree planting in uluhi fern area. Waiaha Spring Reserve.

Planting trees in Waiaha Spring Reserve.

Cleaning around young trees, land of Piihonua, Hilo Reserve.

Working on Pololu horse trail, Kohala Reserve.

Keanakolu-Hopowai truck trail.



Finished section of Popolu horse trail.

Studies of Enzyme Action in Sugar Cane

1. THE CHARACTERISTICS OF ENZYMES AND THEIR IMPORTANCE IN THE GROWTH AND NUTRITION OF PLANTS.

By Constance E. Hartt

Enzymes aid chemical changes:

How plants and animals carry on within their cells the intricate chemical processes which are essential for life, is a question not yet definitely answered. When a cutting of sugar cane is placed in the soil, a portion of the cane sugar stored in the cutting must be digested to the simple sugar glucose before the eye can sprout. This process of digestion takes place at a moderate temperature, since the temperature of a plant is very nearly that of the surrounding soil or atmosphere; but if a chemist wishes to convert pure cane sugar to glucose, he boils the sugar with some acid. Many other chemical processes occur in plants at normal temperatures which require boiling and the use of special reagents to be reproduced in the test tube. *The active agent which enables a plant to carry on a chemical change at a moderate temperature is called an enzyme.* The enzyme which aids the digestion of cane sugar to glucose and fructose is called invertase.

Enzymes are catalysts:

Before continuing with the subject of enzymes a few explanatory remarks about catalysts will be offered, because enzymes are catalysts. It is well known that water is a compound composed of the two elements, hydrogen and oxygen. At high temperatures hydrogen and oxygen combine in the formation of water. This combination of hydrogen and oxygen in the formation of water occurs also at room temperature, but only immeasurably slowly. If, however, some spongy platinum is added then even at room temperature the production of water occurs. Thus the platinum aids the formation of water from the hydrogen and oxygen and enables that process to occur at room temperature. The platinum is an example of a *catalyst,* a substance which merely by its presence speeds up chemical changes.

In living plants and animals there are many substances which speed up life processes, such as digestion, and these substances are called enzymes. Because enzymes are complex organic compounds, they are called *organic catalysts.*

Enzymes have the ability to increase the speed of chemical reactions which would ordinarily take place only very slowly at moderate temperatures. It is thought that enzymes do not cause chemical processes to start, but merely affect the speed of the reactions.

Saliva contains an enzyme:

Familiar examples of enzymes* include the ptyalin of our saliva, a kind of

* See table of enzymes at end of article, which summarizes all the enzymes mentioned in this paper.

diastase which aids in the digestion of starchy foods. Preparations of diastase are sometimes prescribed by physicians to aid in digestion; in fact one good quality attributed to such drinks as "cocomalt" is their diastase content.

It has long been known that the papaya has qualities favorable to digestion, and it has even been suggested that hanging tough meat on a papaya tree will render it tender. Be that as it may, the papaya plant does contain a protein-digesting enzyme of great strength. This enzyme is called papain. Preparations of papain are obtainable on the market and are sometimes recommended to be taken by people suffering from indigestion.

Enzymes are important in many industries:

The importance of yeast in the brewing industry is well known but it may not be so generally understood that the agent within the yeast plant which is responsible for the fermentation of sugar and production of alcohol is an enzyme which is called zymase. Many other examples of the uses of enzymes in various industries might be mentioned, including textile industries, tanning, the preparation of beverages, the preparation of fruit extracts, making bread, manufacture of cheese, production of syrups and confections, manufacture of soya sauce, poultry feeding, ripening of tobacco, fermentation of cacao, as laboratory reagents, and in medicine.

Enzymes are also employed in the sugar industry. Preparations of invertase are used in the analysis of sugars in the laboratory. Invertase is also used in the manufacture of syrups from sugar cane. In South Africa, the use of diastase was recommended for the removal of starch by mills grinding Uba cane, since the presence of starch in the juices leads to difficulties in the process of clarification.

Enzyme activity may be strong or weak:

Enzymes are known by what they do rather than by what they are. Hence the actual amount of enzyme present in a plant cannot yet be expressed, but instead the term "activity" is used, which represents the ability of an enzyme to cause a change in another compound. If the amount of change is great the enzyme is said to be very active, but when the amount of change is small, the activity of the enzyme is weak.

Enzymes are capable of causing a transformation in a very large amount of material; but it is also true that the amount of material converted is proportional to the amount of enzyme present. Thus if a plant has a very weak invertase activity, the digestion of cane sugar to glucose and fructose will proceed slowly; a plant with weak protein enzymes, such as peptase and ereptase, will manufacture proteins only slowly and thus growth may cease.

Special enzymes are required for different kinds of chemical changes in plants:

Enzymes, secreted by the living protoplasm of a cell, are considered essential for almost every chemical change which occurs in a plant. A particular enzyme is necessary for each type of transformation, that is, one special enzyme (diastase) aids in the digestion of starch; another (oxidase) is essential for the process of respiration, which releases energy stored in food used in growth; another

(reducase) aids in rendering nitrates utilizable by plants; and there are many others. Each enzyme is responsible for one particular process, and if a certain enzyme is weak or absent, the process for which it is essential cannot take place normally, and growth may cease or the chemical composition of a plant may be altered.

Composition of plants depends upon enzymes:

Not only do enzymes affect the speed of chemical changes but they may also determine what kind of chemical process may occur in a given plant. Thus according to the kind of enzyme present in a plant, glucose can be broken down to lactic acid, or to alcohol and carbon dioxide. An interesting illustration of the relation between enzymes and chemical composition is the lack of starch in the onion plant, which is associated with the absence of diastase.

The possibility of changing the composition of a plant by introducing a foreign enzyme or bacterial culture into the growing plant was demonstrated recently by Suit and Hibbert (11), who grew potato plants which produced potatoes lacking starch due to the introduction of cultures of a certain kind of germ *(Bacillus subtilis)*, which makes levan (a storage food built up from fructose) instead of starch (a storage food built up from glucose).

Haldane (3) discusses the effect of enzymes upon chemical composition as follows: "Consider a substance A, of which, in the absence of a catalyst, 99 per cent is converted into B, and 1 per cent into C. If a catalyst accelerates the latter process a millionfold, 99.99 per cent will be converted into C, and only 0.1 per cent into B. Hence the fate of A is qualitatively altered. Enzymes do not merely accelerate metabolic processes, they determine their direction." Haldane refers, of course, to the effect of enzymes upon the direction of metabolic processes, not upon the direction of a single reaction. Thus, in the potato described above, the foreign enzyme changed the direction of the metabolic processes connected with the storage of foods from the manufacture of starch to the manufacture of levan; but in a reversible reaction, for example that between maltose and glucose (maltose ⇌ glucose) the enzyme maltase accelerates the speed of the reaction in both directions.

Enzymes are very sensitive to temperature, acidity, chemicals and other conditions:

Temperature has a great effect upon enzymes. If the temperature gets too high, an enzyme is quickly destroyed; in fact enzymes are active only at moderate temperatures. The temperature which destroys an enzyme is specific for each enzyme. For example, the diastase of the bean is destroyed at 131°F. to 140°F.; the protein enzymes of certain bacteria are destroyed at 135°F., and for most enzymes the rapidity of inactivation quickly increases above 122°F. Reducase, however, is not destroyed by boiling. The best temperature for most enzymes lies around 98°F.

Acidity has a profound effect upon the activity of enzymes. If the hydrogen ion concentration is not favorable, the activity of the enzyme ceases or is very weak. Each enzyme requires a certain acidity for its best action, and when either more or less acid the enzyme is less active. Thus if one wishes a particular enzyme to be very active, the acidity must be made favorable. Conversely, if one wishes to prevent enzyme action it is only necessary to render the acidity or alkalinity unfavor-

able. An interesting example of the influence of acidity upon enzyme action is found in the human body. The digestion of meat (protein) occurs both in the stomach and in the intestine; in the stomach the digestive juice contains an enzyme which is active only when very acid and the acidity is furnished by the hydrochloric acid contained in the stomach; but in the intestine there is no acid, the conditions being alkaline, and in the intestine the digestion of meat is carried on by enzymes requiring an alkaline medium.

Enzymes are not only sensitive to temperature and acidity but also to specific salt content. Diastase, for example, is not active in the absence of salts, and its activity is particularly favored by the presence of phosphorus. Oxidase requires manganese to aid in its action. Sugar cane plants deficient in potash were found to have weaker invertase and less manufacture of sugar than plants adequately supplied with potash (5, 6). In the tomato the reduction of nitrates (preparation for use) by reducase does not proceed normally in the absence of phosphorus, potassium, or sulphur. The papaya contains a protein enzyme named papain, the activity of which is stimulated by hydrogen cyanide. Many more examples might be mentioned, but enough have been given to illustrate the importance of specific chemicals in affecting the activity of enzymes. Much remains to be done in this type of research as the field is still young. In a recent review of the subject of the mechanism of enzyme actions, Falk (2) states that one of the most important of the recent advances in enzyme studies is the influence of added substances. The same author considers it evident that enzymes in every living organism must be influenced by the apparently inactive materials present. Such influences, according to Falk, include directive actions, the ability to increase or decrease enzyme activities, and the possible action of one enzyme upon another. Falk states that in a living organism an enzyme never acts in the pure state, and he stresses the importance of the influence of external factors upon enzymes. Oparin (8) has given evidence of the importance of adsorption (a kind of loose attachment) and subsequent removal as a possible mechanism regulating the activities of enzymes in living cells.

What plant processes are affected by enzymes?

Before discussing the life processes in plants which are affected by enzymes, a word about similar processes in the human body may be in order. The food which we eat must be digested before it can give us strength or build up muscles, etc. Digestion occurs in the mouth, stomach, and intestines and in each of those organs enzymes are exceedingly important in speeding up the process of digestion. In the process of digestion, complex solid foods like bread, meat, vegetables, etc., are changed into simple substances which can be dissolved. These simple foods pass through the delicate walls of the stomach and intestines into the blood and are carried to every part of the body, where the food is used to build up new tissues and to furnish strength. To set free the latent strength (or energy) and the heat contained in the food, the food must be burned. This may be compared to the burning of wood or coal to furnish heat. This process of ~~the burning~~ or oxidation of the food takes place all over the body. It requires oxygen which is brought by the blood, having been obtained from the lungs in the process of breathing. This re-

lease of strength and body heat from our food occurs at the temperature of the body, and enzymes are essential for the process.

The metabolic processes in plants which are regulated by enzymes include the *digestion* of foods, processes which require water and are therefore called hydrolyses. Seeds, cuttings and other parts of plants used in propagation contain a supply of food usually in concentrated form, including carbohydrates, fats, or proteins. Before these foods can be used in the growth of plants they must be digested and a special enzyme is necessary to carry on the digestion of each food. Digestion by enzymes is also essential for the removal at night of assimilates stored temporarily in the leaf during the day, rendering complex substances simpler and soluble and readily translocatable. After a food is digested, that is, rendered simpler and soluble, then the process of *respiration* can occur. Respiration in higher plants such as sugar cane involves the utilization of oxygen in the oxidation of foods, and results in the release of energy which is used by the plant for growth and for the manufacture of complex compounds. Just as man cannot live without breathing, so a plant cannot live without the respiration of foods, and for this essential life process several enzymes are required, for example oxidase. The *storage of foods* in plants also involves enzyme action, and it is now generally recognized that the action of most enzymes is reversible. Not only can enzymes convert complex compounds into simpler ones, but they can also build up complex substances from their simpler components. The same enzyme is thought to aid in both the manufacture or synthesis and the digestion of a compound, the direction of the reaction at a given moment whether toward manufacture or toward digestion, being regulated by conditions inside the cell. Armstrong and Armstrong (1) in a new monograph on carbohydrates state: ". . . there is no doubt that in the plant, enzymes function as synthetical agents." Haldane (3), an English authority on enzymes, says: "But where any given reaction is concerned, an enzyme, like any other catalyst, cannot alter the final state of equilibrium, and if it accelerates any reaction, it must accelerate the reverse action to about the same extent." Although the demonstration of the synthetic action in the test tube is exceedingly difficult because of the conditions and lengthy manipulations involved, it has been accomplished with several enzymes, e.g., emulsin, maltase, urease, and pepsin (3). The manufacture or synthesis of cane sugar is attended with especial difficulty, which will be discussed in another report. Oparin and Kurssanow (9) have reported the synthesis of a sugar identical with cane sugar by the simultaneous action of the two enzymes, invertase and phosphatase of yeast. *Other processes* regulated by enzymes include the reduction of nitrates by reducase, the breaking down of hydrogen peroxide by catalase resulting in the formation of water and oxygen, the formation and destruction of the green pigment chlorophyll by chlorophyllase, the fermentation of glucose by zymase, and many others. It is thought that one step in the process of photosynthesis (manufacture of sugar by green plants with the aid of sunlight) is an enzyme reaction.

At every age, in every organ, literally multitudes of chemical changes are taking place in plants, each one regulated by its own enzyme. Each living cell is the seat of many enzymatic processes, and the protoplasm and wall of which the cell is made as well as the food inclusions within the cell are all considered the results of the activities of enzymes. These sensitive agents, readily activated and inactivated by many internal and external factors, are important in many processes absolutely

essential for growth, and regulate many reactions centering around the formation, utilization, and storage of sugar.

Glucose, a simple sugar, undergoes many changes in plants and is greatly affected by enzymes:

It is interesting to speculate upon the fate of a molecule of glucose just formed from carbon dioxide and water by the aid of the green pigment chlorophyll and sunlight in a cell of a sugar cane leaf. It may unite or condense with other similar molecules in the formation of a grain of starch inside the chloroplast and in the evening be released again by the digestion of the starch. It may unite with a nitrogenous compound, go into the formation of a complex molecule of protein, and be used in the formation of protoplasm. It may go through a series of changes not yet fully understood, the ultimate product being fat; as part of a molecule of fat it may form a part of the outer layer of protoplasm and help regulate the permeability of the cell to water and salts. Our molecule of glucose may unite with many of its fellows, lose a lot of water, and result in the formation of cellulose and other cell wall materials. The glucose may go into the formation of pectic substances which may unite with calcium resulting in the calcium pectate layer of the cell wall, which is so important in cementing the cellulose walls of neighboring cells together. Numerous other complex organic compounds, with various functions in the life of the plant, may be formed from glucose. From the standpoint of the sugar industry the most important of these is sucrose, the cane sugar of commerce. The surplus glucose which is not used in the manufacture of complex organic compounds, and which is not used directly for the release of energy in the process of respiration, that surplus glucose according to a theory accepted by many plant physiologists goes into the formation of cane sugar. According to the same theory, the manufacture of cane sugar requires fructose (fruit sugar) as well as glucose (grape sugar), and it is not known whether all the fructose is made from glucose (this process is known to occur, although the mechanism is unknown), or whether some of the fructose arises simultaneously with the glucose in the process of photosynthesis. Plant physiologists today are more and more coming to the conclusion that glucose and perhaps fructose as well, are the primary sugars in photosynthesis. This process of the union of glucose and fructose in the formation of cane sugar, which perhaps takes place both in the leaf and in the stem of sugar cane, will be considered in detail in another paper. All of these metabolic processes are regulated by enzymes.

The fate of glucose in a plant depends upon chance, age, water content, and enzyme activity:

With so many avenues open to our hypothetical molecule of glucose one may well wonder what determines the precise path of any given molecule of glucose. Of course chance plays an important part. If the plant is young and actively growing, much of the glucose will be used in respiration, as young plants require lots of energy just like growing boys. Large amounts of ~~glucose in~~ rapidly growing plants are also required in the building of protoplasm and cell walls of new leaves, etc. The deep-green leaves of young plants are good photosynthetic organs, so that there

is always some surplus glucose to be stored as cane sugar. In an older, more mature plant growth slows down and eventually ceases; in such a plant less glucose is required for current needs and the result is more cane sugar for storage. These comparisons for young and old apply to different parts of the same plant as well as to plants of different ages. Older parts of a plant do not grow but form or store chiefly cane sugar, while young parts grow rapidly and use a considerable amount of glucose.

Another factor determining the course of chemical changes in plants is the amount of water. The importance of curtailing the supply of irrigation water as a means of decreasing growth is well known and has already been discussed elsewhere (7). The formation of starch, cellulose, proteins and other complex organic compounds probably including cane sugar, are known to chemists as condensation processes, and they take place better under conditions of drying out or the withdrawal of water. The digestion of these products requires the utilization of water. Hence the direction of a chemical reaction, whether favoring digestion or manufacture, is largely dependent upon the supply of water in the cell in which the reaction occurs. The cell may have a high moisture percentage, but if water is being withdrawn the conditions for condensation and manufacture are found. The effect of water upon chemical composition was discussed by Spoehr (10) in his study of the carbohydrate economy of cacti; low water content and high temperature were associated with an increase in polysaccharides (complex foods like starch), decrease in monosaccharides (simple sugars like glucose), and increase in pentosans, while a high water content and low temperature were associated with a decrease in polysaccharides, increase in monosaccharides, and decrease in pentosans.

Any factor which decreases growth but does not interfere seriously with photosynthesis is apt to result in increased storage of cane sugar.

One of the most important factors governing the type of chemical reaction, determining the fate of our glucose molecule, is the nature and activity of the enzymes in that particular cell and plant. A plant containing no diastase forms no starch, for example the onion, leek, narcissus. A plant containing generally weak diastase forms starch in comparatively small amounts, for example sugar cane. A plant containing strong invertase forms and stores cane sugar.

Growth and sugar production in the sugar cane plant are processes affected by enzymes:

For a plant to grow normally it must be able to manufacture and digest proteins, since proteins are essential for the formation of protoplasm or life substance. Both the formation and digestion of proteins require protein enzymes, for example peptase and ereptase. Some evidence indicates that sugar cane plants which are weak because of lack of potash, have weak peptase activity and poor formation of proteins (4, 6). The processes of digestion, manufacture of food, formation of protoplasm and cell walls, and respiration—which have already been discussed in this paper—are all essential for growth and are all dependent upon enzymes.

Sugar cane plants deficient in potash had weak invertase activity and poor formation of sugar (6). Other experiments to be reported in a later paper of this series also indicate a relationship between sugar and invertase. One step in

the process of photosynthesis (the manufacture of sugar by green plants with the aid of sunlight) is thought to be an enzyme process.

For many years the increase in the percentage of cane sugar in the sugar cane plant has not been commensurate with the increase in the applications of fertilizers, although the tons of sugar per acre have increased due to the greater tonnage of cane. Economy in handling plant material demands an enrichment of the juices. Because of the great importance of enzymes in regulating growth, formation and utilization of sugar and other chemical processes in plants, and because of the sensitivity of enzymes to fertilizer constituents, acidity, and other conditions, it is felt that studies of the effects of various factors upon the activities of enzymes in the sugar cane plant may lead to a physiological basis for fertilizer applications and other cultural practices as well as to the enrichment of the juices.

Such studies are now under way, and it is our intention to report first upon the functions of invertase and certain factors affecting its activity, and later upon other enzymes in sugar cane.

For convenience, a partial list of enzymes is given, together with the substrates or compounds upon which they act. It is thought by many physiologists that the reverse or synthetic action is catalyzed or aided by the same enzyme although as already stated the synthetic action has been demonstrated in comparatively few instances. The enzymes which we have already studied in sugar cane include invertase, amylase, dextrinase, maltase, peptase, ereptase, catalase, oxidase, peroxidase, and reducase. Others will be studied as time permits.

It is not the purpose of this paper to discuss the details of the studies of the chemical composition of enzymes or the theoretical considerations of the mechanism of enzyme action. Six enzymes have been crystallized and it is said that certain if not all enzymes are proteins (12). The exact chemical composition of enzymes remains to be determined and is a problem for the chemist rather than the physiologist. For a general reference to the subject of enzymes the reader is referred to Waksman and Davison (13).

Partial List of Enzymes in Plants

ENZYME (*a*)	SUBSTRATE (*b*)	END PRODUCT (*c*)
1. Carbohydrate enzymes		
invertase	sucrose	glucose and fructose
maltase	maltose	glucose
diastase	starch	maltose
amylase	starch	dextrine
dextrinase	dextrine	maltose
cellulase	cellulose	cellobiose
cytase	hemicelluloses	dextrines and simple sugars
pectase	pectic substances	simple sugars
inulase	inulin	fructose
2. Protein enzymes		
peptase	complex proteins	peptones and proteoses
ereptase	peptones and proteoses	amino acids
papain	proteins	amino acids

3. Fat enzymes		
lipase	fats	fatty acids and glycerine
chlorophyllase	chlorophyll	alcohol+phytol+chlorophyllid
phosphatase	organic phosphorus compounds	fructose+phosphoric acid
4. Respiratory enzymes		
oxidase	phenol-like compounds	active oxygen
oxygenase	phenol-like compounds	organic peroxides
peroxidase	organic peroxides	active oxygen
zymase	glucose, fructose, mannose, galactose	alcohol+carbon dioxide+ energy
5. Catalase	hydrogen peroxide	water+oxygen
6. Reducase	nitrates	nitrites

(*a*) The generally accepted nomenclature of enzymes today is the addition of the suffix (–ase) to the name of the compound upon which the enzyme acts or the type of reaction catalyzed by the enzyme. Some of the enzymes first discovered were not named in accordance with this method.
(*b*) The substrate is the substance upon which the enzyme acts.
(*c*) The end product is the result of the action of the enzyme upon the substrate.

Literature Cited

(1) Armstrong, E. F., and Armstrong, K. F. 1934. The carbohydrates. Longmans, Green and Co., New York.
(2) Falk, K. G. 1935. The mechanism of enzyme actions. Science, Vol. LXXXI, pp. 471–475.
(3) Haldane, J. B. S. 1930. Enzymes. Longmans, Green and Co., New York.
(4) Hartt, C. E. 1929. Potassium deficiency in sugar cane. Bot. Gaz., Vol. LXXXVIII, pp. 229-261.
(5) ———————. 1933. Studies of the invertase of sugar cane. A preliminary report. The Hawaiian Planters' Record, Vol. XXXVII, pp. 13–14.
(6) ———————. 1934. Some effects of potassium upon the amounts of protein and amino forms of nitrogen, sugars, and enzyme activity of sugar cane. Plant Physiology, Vol. IX, pp. 453–490.
(7) ———————. 1934. Water and cane ripening. The Hawaiian Planters' Record, Vol. XXXVIII, pp. 193–206.
(8) Oparin, A. 1934 Die Wirkung der Fermente in der lebenden Zelle. Ergeb. d. Enzymforsch. 3, pp. 57–72. (Leipzig.)
(9) ———————, and Kurssanow, A. 1931. Uber die enzymatische Synthese des Rohrzuckers. Biochem. Ztschr. Vol. CCXXXIX, pp. 1–17.
(10) Spoehr, H. A. 1919. The carbohydrate economy of cacti. Carn. Inst. Wash. Pub. 287, 79 pages.
(11) Suit, R. F., and Hibbert, H. 1934. A starchless potato induced by the introduction of foreign enzymes. Science, Vol. LXXIX, pp. 78-79.
(12) Sumner, J. B. 1935. Enzymes. Ann. Rev. Biochem., Vol. IV, pp. 37–58.
(13) Waksman, S. A., and Davison, W. C. 1926. Enzymes. The Williams and Wilkins Co., Baltimore.

Some Plant Food Values in Molasses and Filter Cake

By Ralph J. Borden

It is estimated that as a result of grinding some eight and a half million tons of cane in 1933, there were produced therefrom over 200,000 tons of filter cake mud and more than 235,000 tons of molasses, only about 35,000 tons of which were sold. Both of these by-products have been used for many years by our plantation men, and when applied to cane fields we have heard many and varied opinions regarding their value for increasing profits.

In an article discussing "Filter Mud and Molasses" (1) by H. P. Agee, two statements have challenged us, i.e., (*a*) "The agricultural value of molasses is so poorly established that when the market for this material is weak, thousands of tons of it are put into the sea;" and (*b*) "It is possible that unless we take full account of the fertilizing value of filter press mud, and adjust our commercial fertilizers to conform, we may forego the profit we are accustomed to attach to the use of it." Hence we were encouraged to plan a series of controlled "skirmish" tests, using an indicator crop (Sudan grass) in pots which we hoped might enable us to evaluate or determine the relative crop-producing efficiencies of the principal plant foods carried by these two important by-products of the sugar mill, as compared with the crop-producing values in equivalent units of inorganic commercial fertilizer materials. This series of pot studies is at a stage now where we can make a progress report on some of the actual results that have been obtained.

I

We first used an acid soil from Manoa Field 9 that was fairly well supplied with nitrogen but deficient in available phosphate and potash as measured by our Mitscherlich test. (This test indicated 208 pounds of nitrogen, 16 pounds of phosphate, and 316 pounds of potash, per acre foot.) This soil was placed in Mitscherlich pots at Makiki and planted to Sudan grass. No leachate is lost from these pots. Two crops were harvested—the plant crop in 71 days and the ratoon crop in 86 days—hence the soil supported plant growth for a total of 157 days. In all cases the plant foods other than the one being evaluated were supplied in sufficient amounts so that they would not be limiting growth factors. All treatments were in duplicate.

Nitrogen in Molasses (2): For the evaluation of nitrogen in molasses, we prepared the soils by mixing in molasses at the rate of 10 tons per acre, both with and without varying amounts of soluble nitrogen fertilizer. This molasses carried 0.63 per cent nitrogen. The soils were kept warm, moist and well aerated for two weeks before planting the seed.

The results from this soil indicate that where molasses was used to supply nitrogen, the yields of dry matter were consistently lower than where molasses was omitted. There are indications of a "luxury consumption" of available nitrogen as well as indications that the molasses when applied at 10 tons per acre on this soil has either tied up or dissipated some 35 or 40 pounds per acre of otherwise available

nitrogen. It would also appear that the disappearance of this nitrogen took place during the growth of the first crop, since the yields from the ratoón crop, which received no further application of any fertilizer, were very small and showed no significant differences between the various treatments. It seems quite apparent that the nitrogen lost (?) to the first crop was not made available to the crop which followed. (These soils have been set aside, without crop, and will be replanted later in the year in an effort to see if this nitrogen can be recovered for use by another plant crop.)

The following summary (Table I) is offered for those who would care to make their own interpretation of the results:

TABLE I

EVALUATION OF NITROGEN IN MOLASSES

Differential Treatment Identity	Pounds Nitrogen per Acre Supplied From Molasses	From Fertilizer	Total	Dry Weights (Grams) Plant Crop	Ratoon	Total
No N	0	0	0	68.2	11.2	79.4
Mol.	126	0	126	29.9	13.4	43.3
⅓ N	0	104	104	112.8	11.6	124.4
Mol. + ⅓ N	126	104	230	73.7	16.3	90.0
⅔ N	0	208	208	149.6	16.2	165.8
Mol. + ⅔ N	126	208	334	114.8	17.9	132.7
1 N	0	312	312	178.9	16.5	195.4
Mol. + 1 N	126	312	438	146.0	17.1	163.1
1⅓ N	0	416	416	194.5	20.4	214.9
Mol. + 1⅓ N	126	416	542	170.6	19.9	190.5
1⅔ N	0	520	520	176.8	19.4	196.2
2 N	0	624	624	139.4	29.8	169.2

Potash in Molasses: For the evaluation of potash in this molasses, we used a plan somewhat similar to that used to evaluate the nitrogen, except that we applied molasses at the rate of only 5 tons per acre, and we made a second application of nitrogen to the ratoon crop, so that nitrogen would not be a limiting growth factor for the ratoon.

The results from this test would indicate that an application of 5 tons of molasses on this soil furnished sufficient available potash to produce a total dry weight that was slightly better than the optimum application of 426 pounds of potash from sulphate of potash. The further addition of various amounts (106, 213, 320, and 426 pounds per acre) of soluble potash salts to the soil that had received this molasses, did not significantly increase the yields therefrom. (Due to the fact that the molasses sample drawn for chemical analysis was perhaps not a representative one, the actual amount of potash furnished by the 5 tons of molasses used, cannot be reliably calculated.) The total dry yield for both crops, without potash fertilizer or molasses, was 163.7 grams; this was increased to 256.2 grams when 426 pounds of potash fertilizer were used, and to 274.0 grams when only 5 tons of molasses were applied. (These soils have been replanted for another crop without further application of molasses.)

Nitrogen in Filter Cake (3): For the evaluation of nitrogen in filter cake, we used an application of 5 tons of dry cake per acre, which was equivalent to 20 tons

of wet filter cake (77 per cent moisture), both with and without supplementary nitrogen fertilizer applications. Planting was delayed for two weeks after mixing the filter cake into the soil. Ample phosphate and potash were supplied for two crops. The ratoon crop was given no additional nitrogen. (After a six months fallow period, another crop will be grown in pots with this soil without further addition of filter cake.)

The results to date, on this Manoa soil, which are summarized in Table II, indicate that the application of filter cake decreased the yield when no supplementary fertilizer nitrogen was furnished, but when it was supplemented with available nitrogen, its own nitrogen content was perhaps made increasingly available, more or less in proportion to the amount of available fertilizer nitrogen provided:

TABLE II

EVALUATION OF NITROGEN IN FILTER CAKE

Differential Treatment Identity	Pounds Nitrogen per Acre From Filter Cake	From Fertilizer	Total	Dry Weights (Grams) Plant Crop	Ratoon	Total
No N	0	0	0	68.2	11.2	79.4
F.C.	162	0	162	49.7	13.5	63.2
⅓ N	0	104	104	112.8	11.6	124.4
F.C. + ⅓ N	162	104	266	123.2	16.6	139.8
⅔ N	0	208	208	149.6	16.2	165.8
F.C. + ⅔ N	162	208	370	164.8	16.0	180.8
1 N	0	312	312	178.9	16.5	195.4
F.C. + 1 N	162	312	474	200.0	21.4	221.4
1⅓ N	0	416	416	194.5	20.4	214.9
F.C. + 1⅓ N	162	416	578	222.3	24.9	247.3
1⅔ N	0	520	520	176.8	19.4	196.2
2 N	0	624	624	139.4	29.8	169.2

Phosphoric Acid in Filter Cake: For the evaluation of phosphoric acid in filter cake, our plan was the same as that used for evaluating its nitrogen, except that all pots received heavy applications of nitrogen and potash for the plant crop, and in the ratoon crop were given another application of nitrogen (at the rate of 312 pounds per acre). The results (in Table III) indicate quite clearly a comparable and perhaps a greater efficiency of the phosphate contained in filter cake over a water-soluble commercial phosphate material, when the latter was mixed into the high phosphate-fixing, phosphate-deficient, acid-soil type used in this test. (These pots have been replanted and are now growing a third crop.)

A second test (4) on soil from this Manoa Field 9 is a duplicate of the above plan, except: (*a*) the filter cake was used at the rate of 2½ tons per acre; and (*b*) the pots were planted immediately after the filter cake and fertilizers were mixed into the soil, i.e., no "incubation" period was allowed for the partial decomposition of the added filter cake prior to planting. The results from the first crop (given in Table IV) are even more impressive and give to the 295 pounds of phosphate carried by the filter cake applied, a crop-producing value that may be interpolated as equivalent to about 700 pounds of a commercial soluble phosphate fertilizer as used on this high phosphate-fixing soil type.

TABLE III

EVALUATION OF PHOSPHATE IN FILTER CAKE

Differential Treatment Identity	Pounds Phosphate per Acre From Filter Cake	From Treble Super	Total	Dry Weights (Grams) Plant Crop	Ratoon	Total
No P	0	0	0	22.5	116.9	139.4
F.C.	589	0	589	179.5	95.5	275.0
¼ P	0	106½	106½	31.3	120.8	152.1
F.C. + ¼ P	589	106½	695½	163.7	94.3	258.0
½ P	0	213	213	55.6	84.0	139.6
F.C. + ½ P	589	213	802	139.3	94.1	233.4
¾ P	0	319½	319½	77.5	93.8	171.3
F.C. + ¾ P	589	319½	908½	167.3	97.4	264.7
1 P	0	426	426	81.8	83.9	165.7
F.C. + 1 P	589	426	1015	197.3	97.5	294.8
2 P	0	852	852	123.8	94.4	218.2
6 P	0	2556	2556	228.3	89.0	317.3

TABLE IV

EVALUATION OF PHOSPHATE IN FILTER CAKE

Differential Treatment Identity	Pounds Phosphate per Acre From Filter Cake	From Fertilizer	Total	Dry Wt. (Grams) Manoa Field 9
No P	0	0	0	1.4
F.C.	295	0	295	77.9
¼ P	0	106½	106½	10.5
F.C. + ¼ P	295	106½	401½	75.1
½ P	0	213	213	26.7
F.C. + ½ P	295	213	508	72.9
¾ P	0	319½	319½	42.9
F.C. + ¾ P	295	319½	614½	65.8
1 P	0	426	426	51.8
F.C. + 1 P	295	426	721	89.1
2 P	0	852	852	85.3
6 P	0	2556	2556	133.1

II

A second study of some of the plant food values in molasses and filter cake has been conducted at the Hilo Variety Station. The plan used was only slightly different from the one used at Makiki. Three crops of Sudan grass have been harvested from these pots: a plant, a re-plant, and a ratoon; thus this soil has been cropped for a total of over seven months since the by-products that were being tested were applied. The fertilizer treatments (except the application of molasses or filter cake) of the first crop were repeated for the second crop. For the third crop, only sufficient additional nitrogen or potash to keep them from being limiting growth factors, were furnished.

Nitrogen in Molasses (5): An application of Hilo molasses (1.6 per cent N) at the rate of 10 tons per acre on this Hilo soil that was rather high in available nitrogen (414 pounds nitrogen per acre-foot) showed little if any definite effect on the yields that were harvested. In the first crop there may be an indication of very

slightly lower yields when the molasses was added; if so, then in the second and third crops the indication is for a slightly higher yield. However, the differences between comparative treatments are all so small that they may quite naturally be due to the chance errors that can easily be associated with a test of this nature. Even in the third crop, harvested after the molasses was applied, there is very little evidence to indicate that the addition of a rather large amount of nitrogen in the molasses used, has had any definite influence upon the available nitrogen supply of this soil. Unlike the Manoa soil from Field 9 however, the yields have not been definitely depressed by the molasses application that was made. The results are summarized (in Table V) as follows:

TABLE V

EVALUATION OF NITROGEN IN MOLASSES

	Pounds Nitrogen per Acre			Dry Weights (Grams)			
Differential Treatment Identity	From Molasses	From Fertilizer*	Total	First Crop (Plant)	Second Crop (Re-plant)	Third Crop (Ratoon)	Total
No N	0	0	0	75.1	7.9	8.0	91.0
Mol.	320	0	320	74.6	11.4	9.3	95.3
⅓ N	0	208	208	113.3	44.4	12.9	170.6
Mol. + ⅓ N	320	208	528	101.6	48.2	14.5	164.3
⅔ N	0	416	416	135.7	74.8	13.2	223.7
Mol. + ⅔ N	320	416	736	121.3	75.4	17.4	214.1
1 N	0	624	624	140.5	83.1	18.9	242.5
Mol. + 1 N	320	624	944	136.3	84.0	20.6	240.9
1⅓ N	0	832	832	134.4	88.6	18.5	241.5
Mol. + 1⅓ N	320	832	1152	143.4	91.1	24.7	259.2
1⅔ N	0	1040	1040	132.5	76.3	26.9	235.7
2 N	0	1248	1248	130.5	72.7	40.3	243.5
Growing time (days)........................				77	78	64	Total 219 days

* Half in first and half in second crop.

Notes: 1. Fertilization to all pots: First crop at 2556 lbs. P_2O_5 and 852 lbs. K_2O
Second " " 2556 " " " 852 " "
Third " " 426 " K_2O only

2. Soil from Hilo Variety Station (makai); high in N as indicated by the Mitscherlich test.
3. Test run in Mitscherlich pots at Hilo.
4. Molasses mixed into soil before planting first crop, at rate of 10 tons per acre (analysis at 1.6 per cent N, 4.7 per cent K_2O).
5. Nitrogen fertilizer differentials (as indicated) applied to first and second crops but not to third crop.

Potash in Molasses (6): When ample nitrogen and phosphate were furnished, the potash value in molasses was quite comparable with its equivalent from a commercial fertilizer salt. This was apparent in the first crop, thus indicating its immediate availability. The molasses that was used carried 4.7 per cent potash. It was applied at the rate of 5 tons per acre before planting. The following table of results (Table VI) offers some rather interesting data for speculation.

TABLE VI

EVALUATION OF POTASH IN MOLASSES

Differential Fertilizer Identity	Pounds Potash per Acre: From Molasses	From Fertilizer*	Total	Dry Weights (Grams): First Crop (Plant)	Second Crop (Re-plant)	Third Crop (Ratoon)	Total
No K	0	0	0	102.8	62.0	31.9	196.7
Mol.	470	0	470	127.8	58.4	48.4	234.6
¼ K	0	213	213	110.2	71.7	48.6	230.5
Mol.+¼ K	470	213	683	118.4	59.1	51.0	228.5
½ K	0	426	426	120.6	77.7	55.4	253.7
Mol.+½ K	470	426	896	119.9	54.9	63.2	238.0
¾ K	0	639	639	121.5	79.2	59.8	260.5
Mol.+¾ K	470	639	1109	121.9	63.1	68.5	253.5
1 K	0	852	852	121.8	81.4	66.4	269.6
Mol.+1 K	470	852	1322	122.7	64.4	72.6	259.7
1½ K	0	1278	1278	128.9	68.3	68.2	265.4
2 K	0	1704	1704	125.4	81.1	77.3	283.8
Growing time (days)				76	78	64	Total 218 days

* Half for first and half for second crop.

Notes: 1. Fertilization to all pots: First crop at 624 lbs. N and 2556 lbs. P_2O_5
Second " " 624 " " " 2556 " "
Third " " 312 " N only

2. Soil from Hilo Variety Station (makai); indicated by Mitscherlich test to be low in potash and high in nitrogen.
3. Test run in Mitscherlich pots at Hilo.
4. Molasses mixed in at the rate of 5 tons per acre before first planting.
5. Potash fertilizer differentials (as indicated) applied to first and to second but not to third crop.

Nitrogen in Filter Cake (7): Only the nitrogen content of the filter cake was studied in this test at Hilo. Used at the rate of 15 tons of wet (76.3 per cent moisture) cake per acre, with 0.804 per cent N, the filter cake application added 241 pounds of nitrogen to a soil that naturally contained a relatively large available amount of this nutrient. When applied without further supplementary nitrogen fertilizer or with only a relatively small amount, the yields were decreased, especially in the first crop, although in the following two crops there appeared to be a slight yield increase, so that the total yield showed little difference or effect from the nitrogen supplied in the filter cake. When applied with more liberal amounts of commercial nitrogen, this depressive effect of filter cake upon the Sudan grass yields was not apparent, but it is still doubtful if the nitrogen in this filter cake has been responsible for any yield increase on this soil over a period of some seven months of cropping in Mitscherlich pots. The tabulated results are offered below in Table VII:

TABLE VII

EVALUATION OF NITROGEN IN FILTER CAKE

Differential Treatment Identity	Pounds Nitrogen per Acre: From Filter Cake	From Fertilizer*	Total	Dry Weights (Grams): First Crop (Plant)	Second Crop (Re-plant)	Third Crop (Ratoon)	Total
No N	0	0	0	56.9	9.2	4.7	70.8
F.C.	241	0	241	38.5	16.4	7.0	61.9
⅓ N	0	208	208	104.1	55.2	4.5	163.8
F.C.+⅓ N	241	208	449	87.9	62.3	7.2	157.4
⅔ N	0	416	416	119.8	86.7	5.5	212.0
F.C.+⅔ N	241	416	657	121.4	91.1	7.5	220.0
1 N	0	624	624	126.8	105.1	6.9	238.8
F.C.+1 N	241	624	865	122.0	103.2	7.4	232.6
1⅓ N	0	832	832	129.7	94.8	10.6	235.1
F.C.+1⅓ N	241	832	1073	134.6	109.7	10.8	255.1
1⅔ N	0	1040	1040	128.8	102.7	10.5	242.0
2 N	0	1248	1248	133.1	103.4	13.9	250.4
Growing time (days)				68	73	72	Total 213 days

* Half for first and half for second crop.

Notes: 1. Fertilization to all pots: First crop at 2556 lbs. P_2O_5 and 426 lbs. K_2O
Second " " 2556 " " " 426 " "
Third " " 426 " K_2O only

2. Soil from Hilo Variety Station (makai); high in N (over 300 lbs. per acre) by Mitscherlich test.
3. Tests run in Mitscherlich pots at Hilo.
4. Filter cake mixed into soil prior to planting first crop at rate of 15 tons (76 per cent moisture) per acre.
5. Nitrogen fertilizer differentials (as indicated) applied to both first and second crops but not to third crop.

III

A third study concerned with the evaluation of the nitrogen and potash of molasses was carried out at Makiki. Two potash-deficient soils were used: one from Manoa Field 22 and the other from Ookala Field 10 (Kaiwiki Sugar Company, Ltd.). The Manoa soil was very deficient in nitrogen while the Ookala soil had a medium nitrogen supply. The molasses used had an analysis of 0.312 per cent nitrogen and 4.0 per cent potash. It was thoroughly mixed into the soils and allowed to "incubate" for one month before the Sudan grass was planted.

Nitrogen in Molasses (8): The treatments for comparison in this study were different from those which we have previously described. For the evaluation of nitrogen, molasses at 11 and 22 tons per acre (actually 11.38 and 22.76 tons per acre) was used, both with and without a supplementary application of commercial fertilizer nitrogen, and a check treatment carrying the equivalent nitrogen content of the higher rate of molasses application was provided. Ample phosphate and potash were supplied. Here we note a somewhat different effect upon adding molasses to a soil with a low or with a high available nitrogen supply.

On the Manoa soil when the molasses was applied at the rate of 11 tons per acre with no supplementary nitrogen fertilizer, the resultant dry yield was only 15.6 per cent of the yield produced without molasses; when applied at twice this rate or 22

tons per acre, a still further reduction in yield or only 9.7 per cent of the yield without molasses was obtained. When a supplementary application of molasses at 11 tons per acre was given with 312 pounds of fertilizer nitrogen, the resultant yield was only 72.3 per cent of the yield without the molasses; with a supplementary application of molasses at 22 tons per acre, the yield dropped to 42.8 per cent of that secured without the molasses application.

On the Ookala soil, molasses at 11 tons per acre without added fertilizer nitrogen, produced a yield that was 70 per cent of that obtained without molasses; with molasses at 22 tons per acre, the yield was not significantly different from that without molasses. When used to supplement an application of 312 pounds of fertilizer nitrogen, the molasses applied at 11 tons per acre appears to have increased the yield by 11.4 per cent, but applied at 22 tons per acre the yield was not significantly different from that without molasses.

The results follow in Table VIII:

TABLE VIII

EVALUATION OF NITROGEN IN MOLASSES

Differential Fertilizer Identity	Pounds Nitrogen per Acre From Molasses	From Fertilizer	Total	Dry Weights (Grams) From Manoa Soil Field 22	From Ookala Soil Field 10
No N	0	0	0	15.4 ± .48	37.4 ± 3.37
11 tons Mol.	71	0	71	2.4 ± .01	26.2 ± .46
22 tons Mol.	142	0	142	1.5 ± .11	34.1 ± 1.90
½ N	0	142	142	98.4 ± 2.20	123.1 ± 4.74
1 N	0	312	312	137.4 ± 3.14	143.3 ± 4.45
1 N + 11 tons Mol..	71	312	383	99.4 ± 1.03	163.1 ± 1.82
1 N + 22 tons Mol..	142	312	454	58.8 ± 2.13	139.2 ± 4.74
1½ N	0	454	454	133.4 ± 1.94	159.6 ± 4.52

Notes:
1. One crop only of Sudan grass grown in Mitscherlich pots at Makiki; all treatments in triplicate. Harvested at age of 82 days.
2. Phosphate and potash at the rate of 2556 lbs. and 426 lbs. per acre respectively, furnished all pots.
3. Molasses mixed into soil four weeks before planting, and soils kept warm, moist, and aerated during this period.
4. The Mitscherlich test gave the following indications of available nitrogen and potash in these two soils:
   Manoa Field 22 at the rate of 28 lbs. N and 277 lbs. K_2O
   Ookala Field 10 at the rate of 153 lbs. N and 226 lbs. K_2O
5. Molasses was used at two rates of applications: 11 and 22 tons per acre (actually at 11.38 and 22.76 tons per acre).

Potash in Molasses (9): To evaluate the potash in molasses in this study, we used a very small per acre application of molasses—1775 pounds per acre—which furnished 71 pounds of potash. When used both with and without supplementary applications of a potash fertilizer salt, on both the Manoa and the Ookala soils, the potash in molasses was equally as good as its equivalent in the fertilizer, as may be seen from the summary in Table IX:

TABLE IX

EVALUATION OF POTASH IN MOLASSES

Differential Treatment Identity	Pounds Potash per Acre From Molasses	From Fertilizer	Total	Dry Weights (Grams) From Manoa Soil Field 22	From Ookala Soil Field 10
No K	0	0	0	60.7 ± 1.51	63.8 ± 5.22
1/12 K	0	35½	35½	75.9 ± 2.30	90.2 ± 2.44
1/6 K	0	71	71	78.4 ± 2.55	95.5 ± 2.05
Mol.	71	0	71	89.0 ± .80	97.1 ± 4.16
1/3 K	0	142	142	95.1 ± 1.26	98.5 ± .57
1 K	0	426	426	98.6 ± 3.84	117.4 ± 1.03
1 1/6 K	0	497	497	99.2 ± 1.96	113.4 ± 4.73
Mol. + 1 1/6 K	71	426	497	100.6 ± 1.77	112.2 ± .81

Notes: 1. One crop only of Sudan grass was grown in Mitscherlich pots at Makiki; all treatments in triplicate. Crop harvested at the age of 82 days.

2. N and P_2O_5 at 312 and 2556 pounds per acre respectively, furnished all pots.

3. Molasses mixed with soil four weeks before planting, and soils kept warm, moist, and aerated during this period.

4. The Mitscherlich test indicated the following amounts of available nutrients in these soils:

Manoa Field 22 at the rate of 28 lbs. N and 277 lbs. K_2O

Ookala Field 10 at the rate of 153 lbs. N and 226 lbs. K_2O

5. The amount of molasses used was equivalent to an application of 1775 pounds per acre.

IV

A fourth study (10) concerned with the nitrogen in filter cake has been harvested once at Makiki. A soil from Manoa Field 22 and one from Makiki Field 11 were used, and filter cake at the rate of 20 tons per acre (wet basis, i.e., 77 per cent moisture) was mixed into these soils with varying amounts of inorganic nitrogen fertilizer and an adequate supply of phosphate and potash. The pots were planted immediately after mixing.

The results, given in Table X, show a similar trend toward depressed yields from filter cake unless rather large amounts of soluble nitrogen fertilizer accompany its admixture with the soil. (The pots in this test have been replanted.)

TABLE X

EVALUATION OF NITROGEN IN FILTER CAKE

Differential Treatment Identity	Pounds Nitrogen per Acre From Filter Cake	From Fertilizer	Total	Dry Weights (Grams) Manoa Field 22	Makiki Field 11
No N	0	0	0	17.7	37.4
F.C.	162	0	162	5.4	11.1
1/3 N	0	104	104	72.0	106.6
F.C. + 1/3 N	162	104	266	42.7	71.1
2/3 N	0	208	208	102.4	159.5
F.C. + 2/3 N	162	208	370	114.6	117.7
1 N	0	312	312	137.9	203.2
F.C. + 1 N	162	312	474	166.8	168.0
1 1/3 N	0	416	416	155.2	182.0
F.C. + 1 1/3 N	162	416	578	187.1	200.0
1 2/3 N	0	520	520	166.3	221.1
2 N	0	624	624	175.6	226.6

More studies of a similar nature to those discussed herein are being carried on, for it is believed that they can offer us many data concerned with the use of molasses and filter cake as fertilizer material, if they can be correctly interpreted.

General Summary

In this preliminary or progress report dealing with efforts to ascertain the relative value of the plant food content of molasses and filter cake, as compared with their equivalents in commercial fertilizer salts, we have not attempted to arrive at any final conclusions. The tests were conducted merely as skirmish tests, or "feelers," to see if we could obtain yield differences that would warrant further and more careful study. The difficulties connected with accuracy and reliability in such tests as we have conducted are evident to those who have attempted a similar study. Hence the probable error is apt to be rather high, and the yield differences we have obtained must not be interpreted too definitely as the effect of the differential treatment that was given to the pots with the indicator crop used, or as quantitative differences which would be secured in the field with sugar cane.

There are several things that are worth noting however, in this general summary. Chief among these is the fact that the effect produced upon yields when either molasses or filter cake was applied to the soil, varied with different soils, and perhaps the dominating factor which controlled this effect was the available nitrogen content of the soil that received the application. Hence it would appear problematical that we could quantitatively determine a general relative value or percentage efficiency for the nitrogen content of these by-products, for such a figure will undoubtedly be different, dependent on the available nitrogen content of the soil which is used in any specific study.

The results that we have obtained to date, indicate that we may well raise a question about the general advisability of using these carbonaceous by-products on soils that are low in available nitrogen, or on fields where our nitrogen fertilizer application is not made quite liberally. In fact, the question may be raised whenever we use these materials, as to what proportion of the total purchased nitrogen fertilizer cost should be assessed them. We are not as yet certain that the nitrogen withdrawn from the available supply for the decomposition of these materials (either natural or added) will be returned. We are rather inclined to believe that most of it will never be available for further crop growth on these soils, and since we are sure that it was not leached out, we are inclined to ask if it has been lost as elemental nitrogen during the decomposition processes that have taken place.

Both the potash content of molasses and the phosphate content of filter cake appear to be equivalent to the corresponding nutrients in commercial fertilizers. In fact the phosphate of filter cake appears to be considerably more effective than a water-soluble phosphate fertilizer, when used on an acid soil. However, if these materials are to be used for their potash or phosphate content, with the idea of saving money on purchased mineral fertilizer materials, it must be recognized that some of the purchased nitrogen fertilizers will be used by them, and that such nitrogen may probably be permanently lost to the crop. Hence, what at first might appear to be a direct saving in potash or phosphate fertilizer costs, may not actually prove to be as great, when a proper assessment is made against these by-products

for the available nitrogen that is withdrawn by the soil microbiological activity that is stimulated when the molasses or filter cake is applied.

References

(1) Agee, H. P., and Webster, J. N. P. 1932. Filter Mud and Molasses. The Hawaiian Planters' Record, Vol. XXXVI, pp. 61–72.
(2) Agricultural Department Project A-105—No. 45.
(3) Agricultural Department Project A-105—No. 46.
(4) Agricultural Department Project A-105—No. 46-1.
(5) Agricultural Department Project A-105—No. H 16.
(6) Agricultural Department Project A-105—No. H 17.
(7) Agricultural Department Project A-105—No. H 15.
(8) Agricultural Department Project A-105—No. 45A.
(9) Agricultural Department Project A-105—No. 45B.
(10) Agricultural Department Project A-105—No. 46-2.

Two Interesting Pests of Sugar Cane in Guatemala

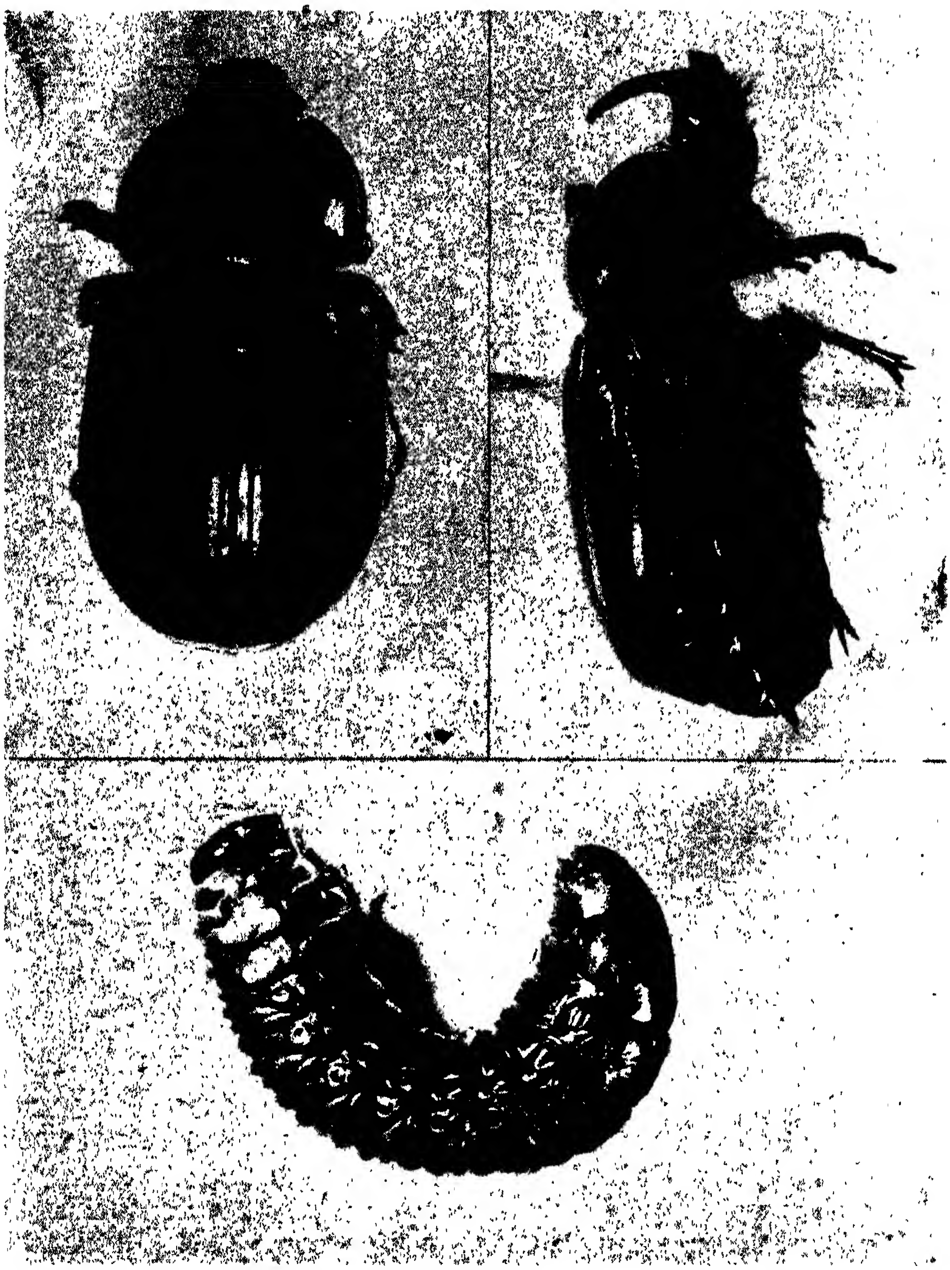
PODISCHNUS AGENOR BURMEISTER AND *SCAPTOCORIS TALPA* CHAMPION

By F. A. BIANCHI

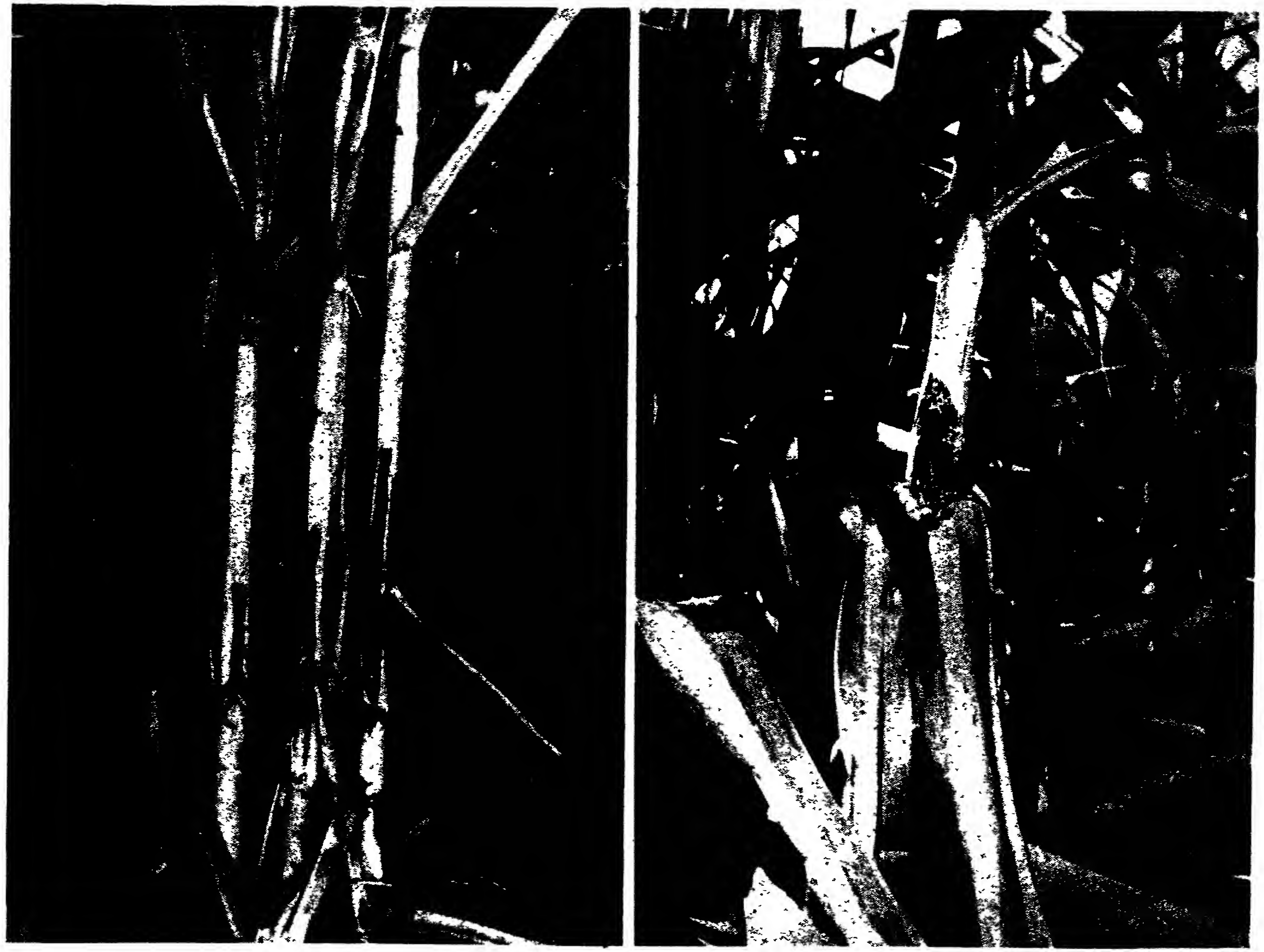
Incidental to the work recently concluded in Escuintla, Guatemala, in connection with the introduction of parasites for *Anomala orientalis*, an opportunity was offered to make observations on the sugar cane pests of that country. Although the moth borer *Diatraea saccharalis* is widespread, no cane pest comparable in the extent of its ravages to our cane leafhopper or to Anomala is known to cane planters there; but the two insects which form the subject of this paper are of great interest and are certainly of potential importance. Both of these pests were previously known from the area where they were observed by the writer, and one of them had already been doubtfully recorded there as an enemy of sugar cane, but the habits of the other one, *P. agenor*, as far as the writer is aware, were heretofore unknown to any but the growers directly affected.

The full-grown grub and adult stages of *P. agenor* are shown in the accompanying illustrations. It is the more widely distributed of the only two species comprising the exclusively Central American genus Podischnus, of the Dynastidae; its range overlapping that of its congener, *P. tersander*, and extending from British Honduras to the Upper Amazon. The long horn-like extension of the head and the peculiar corrugation of the thorax are common to the males of both species, as in other species of the Dynastidae, but they are sufficiently different in detail, although widely variable, to differentiate *P. agenor* from *P. tersander*. The two species also differ in general shape; *agenor* being generally an elongate, oblong insect, while *tersander* is shorter and somewhat dilated posteriorly. In size, the specimens of *P. agenor* collected range from 30 to 36 mm. in length over all, 12 to 14 mm. in width of the thorax, and 16 to 18 mm. in the width of the abdomen, for both males and females.

The habits of the larva are not unlike those of other scarab grubs. In Guatemala it is not known to be of economic importance and showed a decided preference for uncultivated areas, also having been found twice in large numbers in the vicinity of rotten stumps deeply buried in the soil. As might be expected, it appears to practice some degree of upward and downward migration in the soil, for despite its large size it is difficult to find near the surface at any time of the year, except during the beginning of the dry season, in October or November. The larval stage probably lasts not less than two years. One grub collected in the field on November 24, 1932, was then already in the last instar and did not pupate until May 14, 1934, having previously remained about two weeks in a quiescent pre-pupal condition. In the laboratory the larvae ate potatoes quite readily, but did not seem similarly fond of cane rhyzomes. They were evidently extremely hardy, in keeping with their rugged appearance. One, having pushed open the bill box in which it was confined, seemed none the worse after crawling about the cement floor of the laboratory for six days without food.



Upper left: Female of *Podischnus agenor* Burmeister. Upper right: Male of same. Below: Full grown larva of same. (All enlarged.)



Left: Unusually severe damage done to cane by *Podischnus agenor*. Right: More usual exterior appearance of the work of the same beetle.

Of the habits of the beetles much remains to be learned. Whether they occasionally or customarily harm other plants, as is very probably the case, was not ascertained. Their feeding habits, however, have been observed to be of great economic importance to cane growers, and the type of damage which they do to the cane crop is shown in the accompanying illustrations, from photographs taken by Dr. F. X. Williams. This damage is due to the boring of both male and female beetles into the cane stalk for the purpose of feeding, and as seen from the outside, is an unsightly hole about an inch in diameter, often with a loose plug or several strands of fibre hanging out, and always with the rind torn and shredded for some distance up and down from the hole, as if the beetle had to tear the rind before being able to bore its way into the underlying tissues. As observed, the beetles entered, in four out of five cases, near one of the root bands in the upper half of the stalk, and in all but a few cases bored upward rather than downward. When the beetle is finished with the damaged internodes, nothing remains but the empty cylinder of the hard rind and a certain amount of loose, dry fiber, partly bunched at or near the entrance hole or dangling from the walls of the tunnel. Thus, although not more than two internodes are usually destroyed, the damage is probably sufficient to render useless the distal portion of the stalk and to prevent its further growth. More than one beetle per hole and more than one hole per stalk were unusual occurrences; but one of the illustrations shows the longitudinal half of a stalk destroyed so completely as to lead one to believe that more than one beetle must have worked on it.

These beetles were apparently of at least partially nocturnal habits. They were never seen in flight during the day, but were found exclusively within their burrows in the cane, where they seemed to be resting rather than feeding. Whether they came out at night and each beetle crawled back into the same hole in the morning, or whether they came out only once to mate and to bury themselves in the soil to deposit their eggs, as appeared more probable, is a question; but the fact that practically all the females picked out of the cane carried a large complement of eggs was in support of the latter supposition.

Adult beetles may live several months in captivity. Of those that were fed pieces of cane, one female caught on May 12 lived until July 21; a second one caught on the same date died on October 10; and a third caught on June 14 lived until November 7. One emerged in the laboratory and not fed at all, lived only 15 days.

As the last appearance of the beetles in large numbers had occurred at "El Salto", the plantation where these observations were made, some six or seven years before the one observed by the writer, it would seem that the pest is usually well controlled by natural enemies. A large black Campsomeris, as yet unidentified, is found in this region, and it may be important among these natural enemies, for in the laboratory it would readily paralyze the grub, although never known to parasitize it.

If an infested stalk is smartly tapped near a boring, the beetle crawls hastily out, and this reaction was taken advantage of by the plantation to further reduce the pest. Boys paid according to the number of beetles collected in this manner gathered in the neighborhood of 30,000 in two weeks, during the infestation that the writer witnessed in June of 1934.

The second insect herewith illustrated is *Scaptocoris talpa* Champion, family Cydnidae, of the Heteroptera. It was described by G. C. Champion in 1900 from

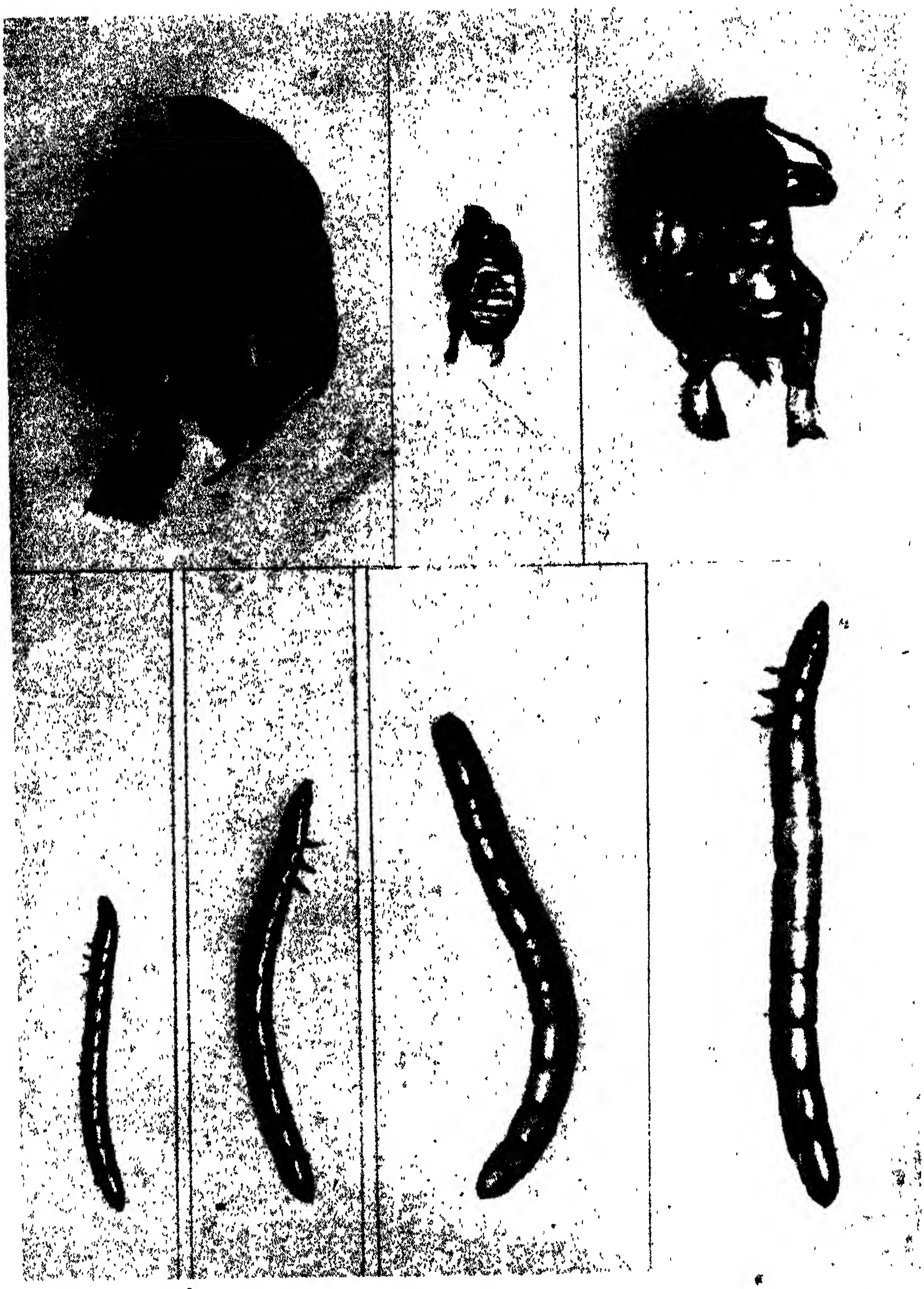
specimens collected in Capetillo, Guatemala, and is closely allied to, but easily differentiated from, the other species of its genus, which, although near to the Asiatic Stibaropus of similar fossorial habits, is limited to Central America and was founded on the Brazilian *Scaptocoris castaneus* Perty. What its range may be is not known. As both Capetillo, from where the species was described, and Escuintla, where the writer had opportunity of observing it, lie in the same region on the West Coast of Guatemala, the range may be rather limited. We have no record of the existence of *Scaptocoris talpa* elsewhere.

Champion ("A species of Scaptocoris, Perty, found at the roots of Sugar-Cane", *Entomologists Monthly Magazine,* Series 2, Vol. XI, p. 255, 1900) implied some doubt that the specimen sent him for description, labelled as having been found at the roots of sugar cane and other grasses, should actually have been feeding on the roots of the cane; but the writer's observations left no room for doubt on that point and showed that the insect so feeding weakened and stunted the cane beyond recovery.

Although found on two or three different occasions and in more than one locality in the vicinity of the town of Escuintla, this insect was generally scarce and abounded only in two small areas. Both of these areas, only one of which was visited, were planted to cane and on the same estate, "Mauricio", about a league from the town. Here the limits of the area of abundance of the pest were very sharp and comprised an extension of only about one acre, where the cane, fourth ratoon, several months old, although of healthy color and appearance, presented a very striking contrast to the immediately adjacent fields in the matter of size and number of canes per stool. The bugs, in all stages of development except the egg stage, could be found in numbers ranging from a dozen to more than 200 per stool, and were very often seen with their proboscises actually stuck into the rootlets of the cane. The stools themselves, however, were full size and showed no symptoms of disease or rot, apart from the fact that only a few of the buds had germinated; showing either that the stools had attained full size during former ratoons before being attacked by Scaptocoris, or had done so in spite of its presence, which must, therefore, have reached maximum abundance about the time the writer visited the area, when retardation of cane growth first became obvious.

The above observations were made on the occasion of a first visit to the infested area, on January 31, 1934. During August of the same year a second visit revealed the bug population practically unchanged or undiminished; but at the time of a third visit, October of the same year, after the field had lain fallow for two months, Scaptocoris were generally scarcer, practically all in the adult stage and many copulating; and a predator which was at first rather scarce had increased in numbers and seemed likely to control the pest eventually.

This predator, which because of its long life cycle could not be reared to maturity within the time available, is the larva of an Elaterid beetle, a species of the Elaterini, adults of which are very abundant in the region of Escuintla and are about the right size to fit the larva in question. When kept in the laboratory these larvae underwent long periods of starvation without showing noticeable effects; moulted once or twice during the year they were kept under observation and only casually fed; and gave distinct evidence of preferring Scaptocoris in all stages of develop-



Upper left: Adult *Scaptocoris talpa* Champion. Upper center and right: Young and old nymphs of the same. Lower figures: Various stages of the Elaterid larva which preys on Scaptocoris. (All enlarged.)

ment to other food, including White Grubs, which they were never noticed to devour as they did Scaptocoris.

Most details of the life history of Scaptocoris are unknown. In both sexes the adults are provided with wings and probably at times undertake to fly, but flight was never observed and adults were seen only in the soil. In the sugar cane area that was badly infested with Scaptocoris, the majority of the population was in the upper foot of soil, but the insect could be found, in all stages of development, scattered down to a depth of 20 inches below the surface. On *Panicum maximum* only three or four specimens were ever found together, always in the upper six or eight inches of soil. Copulation was observed several times in the soil, but only one egg was obtained, and that in the laboratory, from a field-collected female. This egg was smooth, translucently white, longer than thick, equally rounded at both ends, and measured 2 mm. in length by just over 1 mm. in thickness. It did not hatch.

In common with a large number of Heteroptera, Scaptocoris are provided with odoriferous glands which are capable of producing a very repugnant odor. In a thickly infested area on a hot day, slight disturbance of the soil would cause the smell to permeate the air to quite a noticeable degree.

The sexes are indistinguishable by external characters and measure in the adult stage from 9 to 11 mm. in length and from 4¾ to 6 mm. in breadth. The adults may live several weeks in the laboratory if kept in jars of soil with sections of cane. They prefer to puncture the roots which this cane may put forth, but sometimes they also puncture through the rind into the softer zone of adventitious roots, or feed directly on the cut surface of the cane. Of a few individuals collected on August 23, at least one was alive on November 1, 1934.

Sources of Nitrogen

ANHYDROUS AMMONIA *vs.* AMMONIUM SULPHATE *vs.* AMMONIUM NITRATE

By R. J. Borden

In view of the interest that has recently been shown in the possibility of using anhydrous ammonia, dissolved and applied in the irrigation water, as a source of nitrogen, we have conducted several tests during the past year with Sudan grass grown in Mitscherlich pots, comparing equivalent amounts of nitrogen from anhydrous ammonia applied as ammonium hydroxide (NH_4OH), ammonium sulphate $(NH_4)_2\ SO_4$, and ammonium nitrate (NH_4NO_3). All pots were given ample and equal amounts of phosphoric acid and potash. All leachates were returned to their respective pots.

The results indicate quite clearly that the relative efficiencies, as indicated by harvested dry weights, of these three carriers of nitrogen were influenced by the soil upon which they were used.

On the acid Manoa soil (pH 5.6) ammonium nitrate was definitely superior to ammonium sulphate, but there was only low significance to the differences between (a) ammonium nitrate and anhydrous ammonia, and (b) anhydrous ammonia and ammonium sulphate.

When used on the only-slightly-acid Waialua Ranch 11 soil (pH 6.5) there were no significant yield differences between any of the three forms of nitrogen used.

On the neutral Makiki Field 11 soil (pH 7.1) there was a favorable significance to the yield differences favoring ammonium sulphate over both anhydrous ammonia and ammonium nitrate, but no difference between these two latter forms.

The slightly alkaline Waialua, Kawailoa 4 soil (pH 7.5) showed a definite preference for ammonium sulphate over anhydrous ammonia, and a favorable preference for the ammonium nitrate over the anhydrous ammonia. The yield difference between the sulphate and the nitrate was of low significance.

The tabulated results follow:

FORMS OF NITROGEN WITH SUDAN GRASS

Field	Original pH	Average dry yields: grams; (4 pots) Ammonium Sulphate (A.S.)	Ammonium Nitrate (A.N.)	Anhydrous Ammonia (A.A.)
Manoa 9	5.6	85.7±1.7	101.7±2.3	93.6±3.1
Waialua Ranch 11	6.5	167.4±4.4	170.2±1.4	164.8±3.4
Makiki 11	7.1	152.5±4.3	138.8±0.6	136.9±2.5
Waialua, Kawaiola 4	7.5	162.4±3.4	156.2±2.4	137.8±4.9

INTERPRETATION OF SIGNIFICANCE OF DIFFERENCES

Field	Favoring	Difference	Significance of Difference
Manoa 9	A.N. over A.S.	16.0±2.9	High
"	A.N. over A.A.	8.1±3.9	Low
"	A.A. over A.S.	7.9±3.5	Low
Waialua Ranch 11.........	A.N. over A.A.	5.4±3.7	Low
"	A.N. over A.S.	2.8±4.6	No
"	A.S. over A.A.	2.6±5.6	No
Makiki 11	A.S. over A.A.	15.6±5.0	Favorable
"	A.S. over A.N.	13.7±4.4	Favorable
"	A.N. over A.A.	1.9±2.6	No
Waialua, Kawailoa 4........	A.S. over A.A.	25.6±6.0	High
"	A.N. over A.A.	18.4±5.5	Favorable
"	A.S. over A.N.	6.2±4.2	Low

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
MARCH 16, 1935, TO MAY 23, 1935.

Date		Per Pound	Per Ton	Remarks
March	16, 1935.......	3.05¢	$61.00	Puerto Ricos.
"	18.............	3.05	61.00	Philippines, Puerto Ricos.
"	28.............	3.10	62.00	Philippines, Puerto Ricos.
"	29.............	3.1267	62.53	Philippines, 3.10, 3.13; Cubas, 3.15.
"	30.............	3.15	63.00	Puerto Ricos.
April	2.............	3.18	63.60	Puerto Ricos.
"	3.............	3.20	64.00	Puerto Ricos.
"	11.............	3.15	63.00	Puerto Ricos.
"	12.............	3.165	63.30	Puerto Ricos, 3.15, 3.18; St. Croix, 3.15.
"	16.............	3.225	64.50	Puertó Ricos, 3.20, 3.25; Cubas, 3.25.
"	24.............	3.33	66.60	Philippines.
May	2.............	3.25	65.00	Puerto Ricos.
"	23.............	3.35	67.00	Puerto Ricos.

THE HAWAIIAN PLANTERS' RECORD

Vol. XXXIX FOURTH QUARTER, 1935 No. 4

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

John W. Waldron

(Extract from Minutes of a Meeting of the Trustees, H.S.P.A., August 23, 1935.)

It is with profound regret that the Trustees of the Hawaiian Sugar Planters' Association record the death of Mr. John W. Waldron, which occurred in Honolulu on Saturday, August 17, 1935.

Mr. Waldron first became associated with the sugar industry in Hawaii in 1899. He was elected a member of this Association in 1907 and a Trustee in 1911, serving as president in 1921-1922 and 1931-1932. He was appointed a member of the Experiment Station Committee in 1908 and served almost continuously on that committee for twenty-five years and as its chairman for eight years. He had a thorough understanding of every phase of the work being carried on at the Experiment Station and was particularly interested in the control of cane insects and diseases and the development of new cane varieties. It was largely through his influence that the ban on the importation of foreign canes was lifted in 1923. The new canes brought in since that time have already placed the local sugar crop on a much broader and firmer foundation.

He strongly advocated the reforestation of our watersheds and took an active part in the development of a forestry department in the Station.

It has been his privilege to visit almost every sugar producing country in the world, making a study of conditions prevailing in each section involving economic effects applying to the production of cane sugar in Hawaii. He kept very complete statistics pertaining to all branches of the industry, which data were always available to those actively associated with the industry, here in the Islands. This information afforded him the opportunity of rendering valuable services as a representative of the industry at Washington at tariff hearings, and on different occasions in connection with national legislative and administrative matters.

He served as a delegate to several important international sugar conferences and was regarded as being unusually well informed on all matters pertaining to the sugar industry throughout the world.

He was respected and highly esteemed by all of his associates for his friendliness, unfailing courtesy and hospitality, unusual ability and genial personality.

As a token of our esteem for him as a business associate, wise counsellor and friend, we, the Trustees of the Hawaiian Sugar-Planters' Association, take this means of recording our high regard for John W. Waldron and our recognition of his outstanding ability and character, and offer this tribute to be inscribed on the minutes of this meeting.

We extend to his family and members of the firm of which he was the president and manager our sincere sympathy in their bereavement.

In This Issue:

Utilization of Molasses:

Under this heading notes are given on the progress of the work on utilization of the principal by-product of the sugar industry. One of the most attractive possibilities, which is discussed briefly in this issue, is the manufacture of anhydrous alcohol for use in blended motor fuel.

Sugar in Australia:

It is often of interest to learn how the "other fellow" lives and grows his sugar cane. Our delegates to the 1935 International Congress of Sugar Cane Technologists had an opportunity to see how sugar is grown and handled in Australia, and an account of their impressions brings out many points of difference between this Australian industry and ours.

Growth-Failure Problems:

In so far as the so-called "growth-failure" spots represent aggravated effects of deleterious factors which are depressing cane growth in a less pronounced degree over wide areas, they are of special interest to the investigator. The present status of the growth-failure investigations is reviewed and attention is called to some problems which remain to be solved.

Irrigation Labor Requirements and Fixed Charges:

Considerable interest has been shown by the industry in general in the reduction of labor requirements for irrigation. In this article the various factors entering into the initial cost of the particular installation contemplated are discussed together with other factors such as the life of the installation, fixed monthly charges, etc., all of which have a bearing on whether or not the installation will be economical. A chart is presented by means of which the fixed charges of the various phases of irrigation may be estimated. This chart may also be utilized to obtain necessary information about other operations on the plantation.

Life-History Studies of Anomala Orientalis:

Investigations on the life history and general habits of the sugar cane root grub *Anomala orientalis* were made by F. A. Bianchi at Oahu Sugar Company, Ltd., without interruption for an extended period. The results of this research are given in detail.

Emergency Conservation Work in Hawaii:

With the kind consent of E. E. Tillett, Field Supervisor, Emergency Conservation Work for Hawaii, we print a report by Albert Duvel which sets forth all the details of the CCC organization on the Island of Kauai.

Resumé of Papers Presented at the Brisbane Congress:

Short abstracts of papers delivered before the agricultural section at the Fifth International Congress of Sugar Cane Technologists that was held in Australia are offered. All papers, in full, will appear in the "Proceedings" of this Congress and should be available in Hawaii early in 1936.

A Guatemalan Sugar Cane Moth Borer:

Here are given the results of observations in Guatemala on a large moth borer that tunnels the stems of different kinds of plants including the sugar cane. The insect was found in a limited area and was not very numerous in sugar cane, but the cane stem attacked by it often broke at the point of severest injury. Sugar cane is probably not the preferred host of this moth borer.

The male moths fly for a very short time at dusk. The female lays a large number of eggs which she probably scatters over the ground.

This pest is controlled to some extent by ants and a parasitic fly.

The Fluctuations of Sugars in the Leaf Blades of the Sugar Cane Plant During the Day and the Night:

The blade of a sugar cane leaf varies in its chemical composition during the day and the night. The moisture content is least in the early afternoon and greatest in the early morning. The cane sugar content is at its maximum at five or six o'clock in the evening and decreases rapidly during the night. In this investigation sucrose did not at any time disappear entirely from the blades. The relationships between these and several other constituents of the leaves are discussed, with particular emphasis upon the problem of the origin of sucrose in the sugar cane plant.

Liming Acid Soils:

Heavy lime applications on acid soils generally have an adverse effect on juice quality. The experiment reported here attempts to study in somewhat more detail the effect of lime on purity, quality ratio, and glucose. The findings are summarized and presented graphically.

Ceresan Treatment of Seed Cane:

Ceresan is generally acknowledged to be an aid in securing good germination of seed cane during wet and cold weather.

The present test was undertaken chiefly to determine if there was shoot stimulation in addition to increased germination. The results indicate that while H 109 seed germinated better, the shoots were not stimulated but rather depressed by the Ceresan treatment.

Utilization of Molasses

Studies now in progress on products which can be made from waste molasses indicate that several possibilities are worthy of further exploration. One which fits remarkably well into present conditions is the manufacture of anhydrous alcohol to be used in blended motor fuel.

Gasoline containing from 5 per cent to 25 per cent anhydrous alcohol burns in motors of present design with efficiency equal to that of pure gasoline and with no change in carburetor adjustment. It is particularly well adapted to use in the high compression motors of recent years, on account of its high anti-knock value, making the use of tetra-ethyl lead or other anti-knock compounds unnecessary.

Countries without an adequate domestic supply of petroleum have long been carrying on experimental work on alcohol-gasoline blends, and the commercial use of such blends is well under way. In many of these countries an additional motive has been to aid in the disposal of various sorts of surplus material from the agricultural industries. In Sweden, where there is no compulsory legislation, the use of anhydrous alcohol in motor fuel increased from 8,000 gallons in 1922 to 2,150,000 gallons in 1931. In France and Germany, where a small differential tax favors the use of alcohol blends, the latest figures available (1932) show the annual use of 20 million and 46 million gallons of alcohol respectively.

Although the petroleum companies in Europe have generally opposed such blends at first, their attitude is changing and the fuel is now usually blended and distributed by the petroleum industry. In England the Cities Service Company, and in Australia the Shell Company market alcohol blends which are said to be superior to ordinary gasoline.

In Hawaii the annual consumption of gasoline is in the neighborhood of 40 million gallons. To replace 10 per cent of this with anhydrous alcohol would require the use of 60,000 tons of molasses as raw material. The potash from this molasses would be found in the fermentation residue, in an improved condition for use as fertilizer. Other by-products of the process, such as glycerol, fusel oils, and carbon dioxide, are marketable.

From the Fifth Report of the Federal Oil Conservation Board, October 1932:

An analysis of the oil reserves of the United States, based upon the consensus of well-founded opinions, indicates that present known recoverable oil reserves in the U. S. are of the magnitude of ten billion barrels . . . . the equivalent of our present known oil reserves will have been withdrawn from their underground reservoirs in ten to twelve years.

Certain strains of *Aspergillus niger*, a well-known mold, have been found to be efficient producers of citric acid from the sugars in molasses. Work on this process is being carried on.

Several microorganisms have been isolated here from molasses in storage and from spontaneous fermentation of dilute molasses in one of the sugar mills. Results of fermentation with these organisms bear out previous experience that native strains are often most efficient because they are generally best adapted to the raw material used.

A. R. LAMB.

Sugar in Australia

By R. J. Borden

To the "man in the street" in Sydney, New South Wales, there is no excuse for government maintenance of a cane sugar industry in Queensland; to his counterpart in Brisbane, Queensland, this subsidized cane sugar industry is absolutely necessary for his welfare and livelihood. To the political leaders of the Labor Party in Australia, the sugar industry offers a solid block of many thousands of votes; to the opposition it is a target at which they continually hurl charges of "an artificial and uneconomic industry" which the average family has to pay for when it buys sugar. To the nationalist, government support for this industry means his preference for a well-populated, resident-farmer district to the north of Australia's principal cities, rather than the necessity of maintaining fortifications and a plan of coast defense for this long unprotected coast line. Thus any discussion of their sugar industry is apt to be very controversial.

A few general comments on the Australian sugar industry are in order before proceeding to a discussion of their field and milling practices.

Organization

The industry is almost completely under government control, with the Queensland state government responsible for maintaining adequate supplies of sugar for the whole of Australia, the Commonwealth government prohibiting imports, and both of these governments agreeing on the price at which refined sugars will be sold within the Commonwealth. Wages and hours in all branches of the industry are fixed by laws of the Queensland Industrial Court; these are very specific. Prices to be paid by the mill owner to the grower for his cane are fixed by the government's Central Cane Price Board, which is presided over by a Supreme Court judge. This Cane Price Board also makes the land assignments upon which cane may be grown, and only cane grown on these assigned lands is entitled to the benefits of awards under the Sugar Cane Price Acts. These land assignments are non-transferable and the right to grow cane thereon goes with the deed to the land when it is sold. Local Cane Price Boards, one for each mill, have representatives of both growers and millers and are presided over by a government official as local chairman. They maintain a government chemist at each mill during the grinding season.

All raw sugar becomes the property of the Queensland government as soon as it is bagged, and the mill owner is paid for it at prices fixed by government order. The same price for raw sugar is paid to all mills throughout the state, i.e., the mill which is a long distance from the refinery actually receives the same price for its raw sugar as the mill adjacent to the refinery. The present scale of prices gives the grower about 71 per cent of the value received by the miller for his raw sugar.

The government employs the Colonial Sugar Refining Company to handle practically 96 per cent of its raw sugar. Their agreement covers transportation to the

refinery, payment of the fixed raw sugar prices to the millers, refining, selling the refined sugar at fixed wholesale prices within Australia, and marketing the surplus sugar (about 44 per cent of that produced) outside of Australia.

In addition to the Cane Price Board, a government edict requires every cane grower to belong to the Cane Growers' Council. This council has local representation from both the growers and the Australia Workers' Union, and concerns itself with the adjustment of difficulties between these two factions.

A Bureau of Sugar Experiment Stations at Brisbane directs and operates three substations, at Bundaberg, Mackay and Meringa, each with a well-trained technical staff. This Bureau is organized under the Minister of Agriculture and guided by an Advisory Committee made up of government appointees and representative growers and mill owners.

There are 33 mills in Queensland and 3 in New South Wales. These 36 mills put out about 660,000* tons of sugar annually, from some 240,000 acres which are harvested yearly from the total of 300,000 acres that are under cane cultivation. (The average sugar production for the last 10 years has been 2.66 tons per acre.) Since Australia consumes only 375,000 tons** of its sugar, it must sell the rest as export sugar. This export sugar does not receive the internal price but it does enjoy a preferential price of 0.9 cent over the open-world price, in Great Britain and Canada.

Each mill is being operated under what is known as a "Peak Year Quota." This quota is based on the highest production made by the mill prior to 1929. All sugar that is made up to the limit of this quota is paid for in the exact proportion of the annual quantity consumed in Australia and the amount sold overseas. Any sugar made in excess of this quota is paid for at its export value only. Since the internal price paid for raw sugar is set at $82.00† per ton and as the excess production in 1934 brought only $27.00 per ton, there is no object in producing export sugar. (The average price received by the farmer for the last three years has been $58.00; this year he expects to receive $55.50, of which $50.00 is being paid outright and the balance held until the final rates are adjusted.)

Because of this "Peak Year Quota" each mill tells the grower how much cane he may deliver to the track line weekly during the grinding season. This cane must come from specific land areas that have been officially assigned to cane growing; no new land and no land exchange may be used.

Fifty per cent of the cane grown comes to 18 cooperative mills; 25 per cent comes to mills owned by the Colonial Sugar Refining Company, and the other 25 per cent goes to other privately owned mills.

* All tonnage figures are "short" tons that have been converted from "long" tons.

** This is a high per capita sugar consumption and may be compared with other places as follows: (1) Denmark at 135 pounds; (2) Australia at 124 pounds; (3) Hawaii at 117 pounds; (4) United Kingdom at 116 pounds; (5) Switzerland at 114 pounds; (6) Sweden at 110 pounds; (7) U. S. at 108 pounds; (8) Canada at 102 pounds; and Italy at 18 pounds; Central America at 16 pounds; Soviet Union at 13 pounds and China at 3 pounds per capita.

† All currency figures have been converted from Australian pounds, shillings, and pence on the basis of $4.00 per Australian pound.

In 1904, a group of mills which was heavily indebted to the government was taken over and operated by the government. This operation was not successful, so in 1911 the Cooperative Act was passed and the mills were turned back to the growers. (They still owe the government some three and a half million dollars.) The present cooperative mills are of two kinds; (1) those owned entirely by the growers, and (2) those controlled by outside capital. Each has its own charter, and each stockholder is entitled to one vote only, regardless of the amount of stock he holds. They elect directors for a three-year term, and these directors appoint the mill manager. A certain amount of the profit made by the mill must go into a reserve fund to be used in "lean" years. However, the directors tend to pay out the profits and to let the milling plant and equipment run down. These cooperative organizations enjoy cooperative buying privileges, and the farmers receive more money for their cane, so that at the end of the year there will be a few profit-taxes to pay the government.

All cane field and factory workers, except members of the farmer's family, are required to hold membership in the Australian Workers' Union, and non-union labor may not be employed as long as union labor is available. The Industrial Court of Queensland has laid down a definite set of regulations covering the signing on of laborers, their working hours, accommodations, food, holidays, lost time, and time and amount of payment for the various kinds of work done. They have set down specific terms of agreements with cane cutters. Thus, the 28,000 laborers in the sugar industry are adequately protected and paid for their work, and the 8,000 cane farmers can like it or not, just as they please. Naturally the farmers do not like this labor situation, especially since (according to a public address by the Minister of Agriculture at the dedication of the new Meringa Experiment Station) "the average income of the average cane farmer is little if any better than the average income of the average worker who has no capital invested in the industry." Thus it would appear that the protection being afforded by the Australian government to its sugar industry is quite definitely for the benefit of labor and is probably not aimed at that happy prosperous small-farmer population which the nationalist wants to see established along the Queensland coast.

Agricultural Practices

Any discussion of the agricultural practices in the Australian sugar industry must be informative and will unconsciously be comparative. A comparative review of an industry that is conducted under a set of very different economic and political, as well as agronomical conditions, particularly when such a review is made by one who has had only a very brief contact with it, is difficult to present and may even be unfair. However, I shall try to give you some of the general impressions that the sugar industry in Australia has left with me. Many of the data were secured from individual opinions, and we had little opportunity to review reliable data; hence, some of our observations may not be reliable. They are offered, however, in good faith with the hope that they are approximately correct and without too great discrepancies.

Environmental Factors: The excellent natural conditions of climate, soil, and

water, that favor the sugar-growing regions of Queensland are in a large way responsible for the fact that they grow there "the sweetest cane in the world." An idea of these favorable climatic conditions may be gathered from Table A which shows the average temperatures and humidity and total rainfall during the growing and harvesting seasons for the principal sugar-growing centers. Higher maximum temperatures, higher minimum temperatures, higher humidities, and greater rainfall occur during the growing season, when such factors make for rapid cane growth, and the cooler temperatures, lower humidities, and dry weather come when it is most desired to favor good juices.

TABLE A—QUEENSLAND CLIMATIC DATA

District	Growing Season—December to May (inclusive) Mean Max. Temp.	Mean Min. Temp.	Relative Humidity	Inches Rainfall (6 Mos.)	Harvest Season—June to November (inclusive) Mean Max. Temp.	Mean Min. Temp.	Relative Humidity	Inches Rainfall (6 Mos.)	Total Annual Rainfall
Bundaberg ...	83.2	65.4	70	31.3	76.6	55.3	68	11.0	42.3
Mackay	83.0	69.3	76	55.8	76.6	59.5	72	11.5	67.3
Ayr	86.8	68.9	70	34.9	81.4	59.4	64	6.8	41.7
Innisfail	84.8	69.5	82	113.3	79.7	61.5	80	29.3	142.6
Cairns	87.3	71.7	74	74.7	82.5	64.8	70	13.7	88.4

Latitudes: Bundaberg 25°, Mackay 21°, Ayr 19°, Innisfail 17°, Cairns 16°; (Hawaii is at 20° north latitude).

Although some cane had been laid flat by heavy winds, there was little evidence of split or shredded leaves such as result when strong winds are continuous. Some of the cane area suffers an occasional frost and cool nights often prevail throughout a large part of the region. Thus there is considerable evidence of banded chlorosis.

The cane lands are generally flat and there are but few hilly, rocky fields to be found.

In general, the better cane soils are well-drained, sandy, alluvial loams. They are quite loose and deep and are low in organic matter, but generally of good texture and well supplied with both phosphate and potash. There are practically no alkali soils and few that are calcareous. Some few alluvial clays tend to run together and bake after a heavy rain. There are two chief types: (1) the red volcanic soils which are quite deep, but have a low available moisture content; they tend to be quite acid and are low in organic matter; they have an ample supply of available phosphate but are deficient in nitrogen and potash; and (2) the alluvial soils which are wet, cold and poorly drained, overlying a high water table; they are deficient in nitrogen but well supplied with minerals.

In districts where irrigation is needed, there is apparently an adequate supply of water not far below the surface. In some districts this water carries too much salt, and at one place they are anticipating trouble from water with 60 grains per gallon because the salt is accumulating due to a poorly drained subsoil. At another center, where the underground water level is being lowered by heavy pumping, the salt content of the water is increasing from year to year.

Preparing for Planting: There are only two real large plantations in Queensland which operate heavy tractors and implements for preparing their land for planting. The average 40-acre farmer cannot afford such heavy equipment. He prepares his land for planting by plowing with single- or double-disc riding plows

pulled by small tractors in some cases, but generally by a team of horses. The soil is plowed to a depth of about 10 inches and all trash is plowed under. Notched discs or springs on the plow frame are used to hold the trash down to the ground, and various types of trash cutters are used before plowing. Where a tractor is available a grubber or subsoiler follows this disc plowing.

Fields that are to be planted are cut early (in August). The rotary hoe is then used, usually twice, to cut up the trash and stubble. This works to a depth of 4 inches on heavy soils and 7 inches on lighter soils. The chisel grubber, which works 10 to 12 inches deep, is also used. The land is then left for about 6 weeks to allow the trash to decompose. At this time it is a general practice to sow a legume crop. This may be the Mauritius bean, the giant cow pea, or the Poona pea (Vigna katiang). The seed is broadcast and covered either by another rotary hoeing or with a disc harrow, which operation also further chops up any undecomposed trash. Nothing further is done until the green manure crop is ready to turn under. The legume crop is plowed under about 12 inches deep. The land is then fallowed for another month or six weeks, and is then harrowed and planted (in April). From 3 to 5 plowings with intermediate harrowings are quite common when preparing land for planting between September and March.

There is a gentlemen's agreement not to plant cane in a field the same year it is cut. Hence about 25 per cent of the total cane acreage is planted to a legume green manure crop.

Planting: The planting season in the irrigated district is from March to May; in the unirrigated districts it is from May to July. The entire stalk is used for seed, being cut up into 10- to 12-inch seed pieces, planted in freshly opened deep furrows that are 4½ to 5 feet apart, spaced about 3 inches in the row, and covered 4 to 6 inches deep to assure contact with moist soil. We found no farm where top seed only was used for planting. In general, the stand of cane in plant fields appeared very thin, and it was felt that the use of body seed was the cause of this. Very little attention is paid to replanting and spotty stands are common.

Practically all farmers use some type of planting machine, which plants and covers 5 to 8 acres a day. The larger machines open the furrow as well, and some of them have fertilizer attachments.

Cane Varieties: The Australian sugar planter who plants a cane variety that is not on the approved list as laid down for his particular mill by the Cane Price Board is liable to a deduction of as much as $2.00 per ton from his payment for cane delivered from such variety. The reason for this "variety approval" is to get rid of canes that are susceptible to the prevalent cane diseases of the various sugar districts. The principal varieties grown and from which over 75 per cent of the sugar comes are Badila, M 1900, H. Q. 426, E. K. 28, D 1135, Q 813, and H. Q. 409.

The Bureau of Sugar Experiment Stations, in its standards for the selection of new cane varieties, emphasizes resistance to disease (especially gumming), an erect growth habit, a high sucrose content, and an ability to make full use of a six-months' growing season and be mature in 12 months. Major emphasis is placed on resistance to disease, and the various crosses are judged by the mass action of their progeny to the most serious disease of the district where they are grown. Recom-

mended as resistant to gumming, and for the dry, red, volcanic soils are POJ 2878, POJ 2725, Co. 290, POJ 234, Oramboo and Korpi; for the alluvial soils are Q 813, Oramboo, Korpi, POJ 2725, POJ 2878 and Co. 290 (the latter on poor lands only).

Since all mills eventually figure payment for their cane on the basis of its sugar content, greater emphasis is placed on a high-sucrose cane than on a cane which might make more total sugar but requires more cane per ton of sugar to do so.

Irrigation: Twenty per cent of the total sugar is grown with irrigation. The average cane yield per acre for irrigated lands is 36 tons as compared with an average of 19 tons for the whole of Queensland.

Small irrigation plants owned by individual farmers are the rule. Sub-artesian water is pumped from 4- to 6-inch "spears" that have been driven into water-bearing sand some 15 to 40 feet below the surface. About six of these "spears" are connected to a single pump. One large irrigation project pumps its water from an adjacent river supply. Some Diesel and some electrically driven pumps are used. There are also quite a number of "producer-gas" plants which use gas from wood-burning outfits to run the pumps. Storage reservoirs are an exception. Most of the land is flat and little fluming is noted.

The long-line system of distribution is generally used. Small pipes at the head of each line take the water from the level ditch. These pipes are removed after each irrigation to prevent damage to them by the cultivating implements. The lines appeared to be too long; some were over 900 feet in length and had had water running in them for six hours and it had not yet reached the ends. One man was handling 35 lines that were opened at one time. His daily coverage was estimated at about 20 acres and he was applying about 7 acre-inches per acre.

The first irrigation to plant cane is given on top of the seed in a deep furrow After this furrow becomes filled with enough soil to hold the cane erect, the water is changed to a furrow between the lines. When irrigations are necessary the intervals may be as close as 10 to 15 days. However, one plantation reports that last year they applied only 8 rounds to plant cane, 6 to first ratoons, and 10 to second ratoons; they used an 8-inch irrigation at 3-week intervals, and the irrigator covered about 4 acres per day.

Fertilization: There is a wide variety of fertilizer practices. There is an almost unanimity of opposition to the use of large nitrogen applications which result in such rank, succulent growth that the cane will lodge, because lodged cane is very unpopular in Australia.

In the use of commercial fertilizers, the general practice is to apply a mixed fertilizer with the seed or immediately on ratoons and to follow with ammonium sulphate when the cane is knee-high. At most places this is applied by a single-row, animal-drawn machine with a vibrating type of hopper. This mixed fertilizer is primarily composed of meat packers' by-products, the P_2O_5 being largely organic.

A need for phosphate and potash on many of the alluvial soils has not been definitely shown, and it is rather difficult to justify the high phosphate content of the mixed fertilizers that are being used thereon, unless the reason be a political one.

Filter cake is generally used as fertilizer by the larger estates but there are few data to show its value.

Fig. 1. Irrigating two sides of the line in five months old Badila.

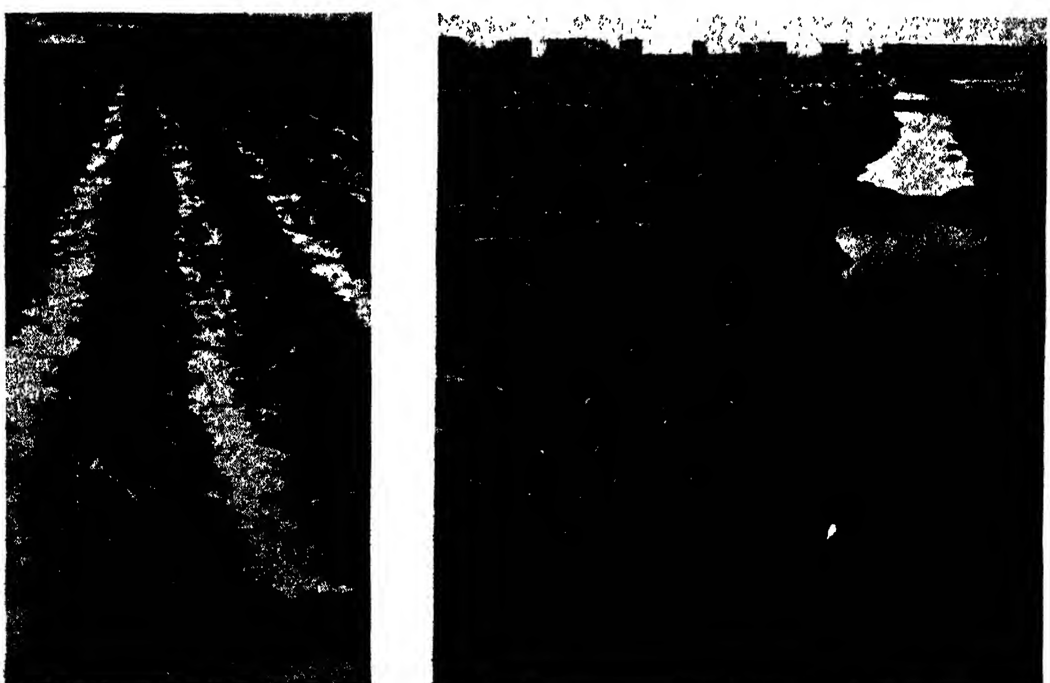


Fig. 2. Long-line irrigation in the Ayr district.

The use of molasses is confined to the large estates near the mills because the transportation to small outlying farms is too costly. Data from yield trials were not available but it is claimed that an 8-ton application of molasses has resulted in a 10-ton gain in cane tonnage. The molasses is applied hot and directly from trucks to the row middles of plant cane when the cane is about one foot high, and to ratoon fields right after harvest. It is worked into the soil with the rotary hoe and may be supplemented with a dressing of superphosphate. The molasses application is generally followed 2 months later with 200 pounds of ammonium sulphate, and with another 200 pounds of the same nitrogen salt at closing-in time.

In order to indicate the amounts of fertilizer applied per acre, we give a few specific practices that are used:

(*a*) 300 pounds of 2-17-8 followed by 300 pounds of ammonium sulphate; this furnishing about 69 pounds of nitrogen, 51 pounds of phosphoric acid, and 24 pounds of potash.

(*b*) 320 pounds of 5.2-16.1-0 followed by 600 pounds of ammonium sulphate in two applications; which would furnish 143 pounds of nitrogen and 52 pounds of phosphoric acid.

(*c*) 400 pounds of 3-12-16 followed by 300 pounds of ammonium sulphate; or 75 pounds of nitrogen, 48 pounds of phosphoric acid and 64 pounds of potash.

(*d*) 320 pounds of 11-7-2 only; (35 pounds of nitrogen, 22½ pounds of phosphoric acid, and 6½ pounds of potash).

(*e*) 300 pounds of 8-10.6-8 only; (24 pounds of nitrogen, 32 pounds of phosphoric acid, and 24 pounds of potash).

(*f*) 15 to 20 tons of green manure carrying perhaps 200 pounds of nitrogen plus 400 pounds of superphosphate; (80 pounds of phosphoric acid).

(*g*) 500 pounds of 1-17-7½ followed by 300 pounds of ammonium sulphate; (68 pounds of nitrogen, 85 pounds of phosphoric acid and 38 pounds of potash).

(*h*) 600 pounds of 7-10-10 followed by 300 pounds of ammonium sulphate; (105 pounds of nitrogen, 60 pounds of phosphoric acid and 60 pounds of potash).

Cultivation: Cultivation of plant cane is thorough and continuous until the crop is covered-in. Since the seed has been covered deeply, it is common practice to use the "spinner" directly on the cane row to remove a small amount of soil and the small weeds growing therein before the cane shoots are very far out of the ground. Sometimes the "spinner" is run twice in the cane row to clean out young weeds developing there. It requires considerable skill to run this spinner and avoid going too deeply and this work is generally done by the farmer himself. In addition to the spinner, the "cotton king" harrow and the "sun weeder" cane cleaner and cultivator are in general use for cleaning the cane line until the cane is a foot and a half high. At one farm cane that was three months old had had 3 cultivations; once with the harrow and twice with the cane cleaner. These implements are pulled by horses; few mules were in evidence, nor were there any small-type garden tractors used for motive power. Practically all cultivators are the walking types.

Fig. 3. The "spinner" removing soil and small weeds from the cane line.

Fig. 4. Cultivating plant cane with a six-tine grubber working about 12 inches deep.

This continuous use of cultivators is claimed to be necessary for weed control and to conserve moisture. A wide variety of tools for cultivating between the lines is found and every farmer seems to have a great many of them. The deep-tine grubber and the one- or two-horse cultivator, as well as a small rotary hoe with small moldboard to open a furrow for irrigation, are common. In spite of the extensive use of cultivators, it is necessary to do some hand hoeing in some fields. There is no question that weed growth in plant fields is at a minimum. The soils appear easy to work and plant cane looks generally vigorous, although the color is slightly yellow. The use of implements appears excessively frequent and deep. The amount of work that might be accomplished with these machines could be increased if they had riding attachments. It is rather hard to fit the high-priced labor policy into the scheme of cultivation that is found operating.

When cultivation of the plant crop is completed, the deep planting furrows have been filled and even slightly hilled-up. This may be one reason for the few ratoon crops they are able to take off; they do not average two ratoons, and it appears that much more attention is given to planting than to ratooning.

The cultivation of ratoons is accomplished after burning-off the trash or rolling it into alternate interspaces. Where the trash is burned, both long and cross harrowing with either disc or spike-tooth harrows are practiced. This operation, in addition to leveling off the field, mulching the surface and getting the early-started weeds, destroys the upper eyes of the cane stubble and forces the ratoon crop to develop from the lower eyes. This growth results in much larger sticks.

Cultivating implements for ratoons are set to work very close to the cane line. The rotary hoe and a grubber with two sets of three teeth that work 12 inches deep are in common use. Off-barring both sides of the line, and the use of the stubble shaver for cutting down stubble in irrigated fields, both find a place in ratoon cultivation. Much of this cultivation appears to be very destructive to the root system and certainly prevents the stool from widening out; and with all this implement cultivation ratoons need hand hoeing in the cane lines. Only about 30 per cent of the total crop in Australia comes from ratoons and in general there is a decreased yield of about 10 tons for each successive crop after the plant crop, e.g., the average yield of plant cane in one district is 50 tons per acre, of the first ratoon crop 40 tons, and of the second ratoon 30 tons. No root disease was evident. Some farmers get no ratoons at all; irrigated lands usually get at least two ratoons, but unirrigated lands average less than two.

Diseases: The principle of disease control in Australia is based on the selection of resistant varieties. They aim at control rather than eradication. This policy is apparently very successful, since many serious diseases are present, yet on the better farms disease was rather hard to find. Where it was found, however, the intensity of the infection, except mosaic, was very severe.

The following diseases were noted: Gumming, leaf scald, Fiji disease, downy mildew, chlorotic streak, dwarf disease (a new disease confined to a very limited area at present), and a cane-killing weed (striga)—a parasitic weed that gets into the rhizome of the cane and kills the stool.

It was of interest to note that mosaic disease is not widely spread in northern Queensland. The aphis that spreads mosaic was present but there was very little grass present for this host aphis to develop on. It is quite possible that either the

Fig. 5. Tractor-drawn rotary hoe for cultivating, with furrow opener to prepare lines for irrigating.

Fig. 6. Applying fertilizer. (The only mule we saw in Queensland.)

clean field culture or the frequent plowing and planting of cane may be the reason for mosaic not spreading in Australia, or perhaps some climatic factor may exist that is unfavorable to the spread of mosaic there.

Insects and Pests: The cane grower also has to contend with the cane root grubs, both the moth and the beetle borers, armyworms, wire worms, white ants, and rats. The first and last named of these pests are extremely destructive. By speeding up the rotary hoe, one plantation is apparently doing a lot of damage to the white grubs that are contacted. By an energetic rat campaign which includes poisoning, trapping and burning-off heavy vegetation that harbors the rat population, these animals are being somewhat controlled.

Harvesting: Plant cane is cut at 14 to 18 months, while ratoons are harvested ahead of plant crops at 10 to 12 months. The small farms harvest about 30 acres of their 40-acre assigned lands each year.

Most of the cane is cut unburned. This is because the mills are unable to control the delivery of burned cane within the 48-hour period after its cutting, that is desirable to prevent deterioration.

Very few of the cane farmers do their own harvesting, although they do perform most of the other field work connected with raising their cane crop. Consequently the harvesting work is left for a body of strictly seasonal laborers, a highly unionized group who work under very strict regulations.

These itinerant cane cutters work in small groups of 6 to 10 men each. They are required to cut, load, and lay portable track. In 25-ton cane they were averaging 4½ to 5½ tons a day; in 60-ton erect Badila cane they were making 7 tons a day. Hence the laborers produce a good day's work.

The full length cane stalks are loaded on crosswise and tied down with chains to small, steel-frame cars that weigh about 700 pounds and carry 2 tons each. These cars run on 24-inch track. When the main track line is too distant from the field these cane cars are hauled into the field on wagons that are fitted with rails on which the car rests and from which it may be rolled off onto the rails of the main line.

There are many specifications concerning the cane that the mill may accept from the grower. Cane with less than 7 per cent C.C.S., which is equivalent to a quality ratio of 14.3, is not accepted by the mills. Deductions in the price paid by the miller to the grower are made for burnt cane except when the cane was accidentally burned by the mill owner's locomotives or employees. A deduction may also be made for diseased cane and for cane that is not an approved variety. Cane with more than 3 per cent trash, tops, dirt, dry or rotten cane is not accepted and must be cleaned at the grower's expense.

A mechanical cane harvester was in operation at one of the larger plantations and it was doing a fair job of cutting and loading burned 25-ton, erect cane at the rate of about 10 tons per hour. Its future is problematical since the labor organizations are not especially interested in the development of machinery that may increase the list of unemployed.

Transportation: Cane is transported to the main line on portable track, on wagons, and by motor truck, by the farmer. On most farms the cane tonnage is too light to make the use of portable track in the field economical. There are but few derricks and hoists at the main lines to use in transferring cane to the railroad

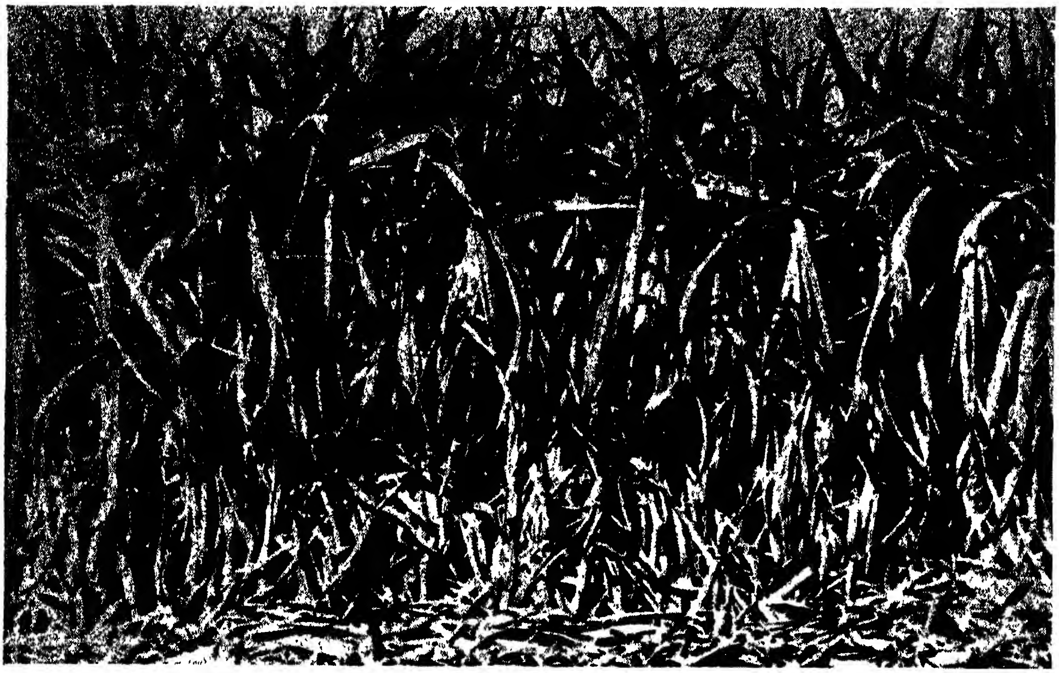


Fig. 7. Sixty-ton Badila cane 18 months old.

Fig. 8. Harvesting unburned Badila cane.

cars. Hence, it is a common sight to see the loaded, small cane cars mounted on wagons being unloaded directly to the main track line.

Milling Practices: The method of unloading cane at the mills in Australia is by use of the Davis rake and the tilting platform on which the cane car is tipped and the load dumped onto the carrier. Thereafter a double set of levelling knives is used; the first set levels the cane, while the second set does most of the cutting.

Ninety per cent of the mills use National shredders. These prepare the cane for the diffusion process which is almost universally used. The use of these shredders and the fact that the mill is rigid makes it necessary to use pushers. The mill grooves have a 2-inch pitch. The mills are spaced as far apart as 60 feet, and it takes the cane about 20 minutes to travel through a Queensland mill. The diffusion baths are kept at a temperature of 180 degrees to 212 degrees F. Fifteen per cent of the total steam is used at this place. Twenty to twenty-two per cent imbibition water is used on the cane. Generally speaking the milling in Australia is costly.

Boilerhouse Work: Pipe lines are in general poorly insulated, resulting in considerable loss of heat. Short stacks make it necessary to use forced draft. The moisture in the bagasse runs from 44 to 52 per cent. Nearly all mills find it necessary to burn extra fuel, this is chiefly wood, but some coal is used. Most of the milling plants are very old. The Colonial Sugar Refining people particularly make a wide usage of instruments to measure work within the mills and spend a large part of their off-season time working up the data secured with these instruments.

Clarification: The Petree process which was formerly used has been abandoned. The C. S. R. subsiders are in general use and may be the reason for poor clarification, since the juices are not clear. Hot limed juices tend to have a pH of about 7.4. The subsiders are used to economize on presses, cloth, etc. The claim is made that a thicker mud is obtained than from the Dorr clarifiers. The mud from the subsiders is either sent to the fields or dumped into the rivers. All C.S.R. mills use double filter presses.

Evaporating: Syrups are evaporated to 72 Brix. Molasses is not diluted.

Boiling is done direct with live steam under a low steam pressure. There is evidence of molasses fermentation over the week end.

Pans: Coil pans are preferred, using exhaust steam at low pressures—5 to 6 pounds. It takes a long time to boil a strike—8 to 10 hours. There are some calandria pans in use.

Centrifugals: The centrifugals use steam for drying. The 48-inch machines are run at 850 r.p.m. from overhead belts which appear dangerous. These machines are bottomless and discharge when stopped.

Dryers: Practically all mills have taken the tubes out of their dryers and are using the dryers as coolers.

Bagging: Sugar is bagged in 160-pound bags which are closed by machines after filling.

By-Products: Molasses is used in the manufacture of alcohol, for fertilizer, and for stock feed, or it may be spread on the bagasse and burned. A mixture of gasoline and 15 per cent alcohol is marketed under the trade name of "Shellcoll."

Filter cake and mill ash are used as fertilizers or thrown away. The bagasse is all burned.

Fig. 9. Transportation of cane on small cane car mounted on a wagon.

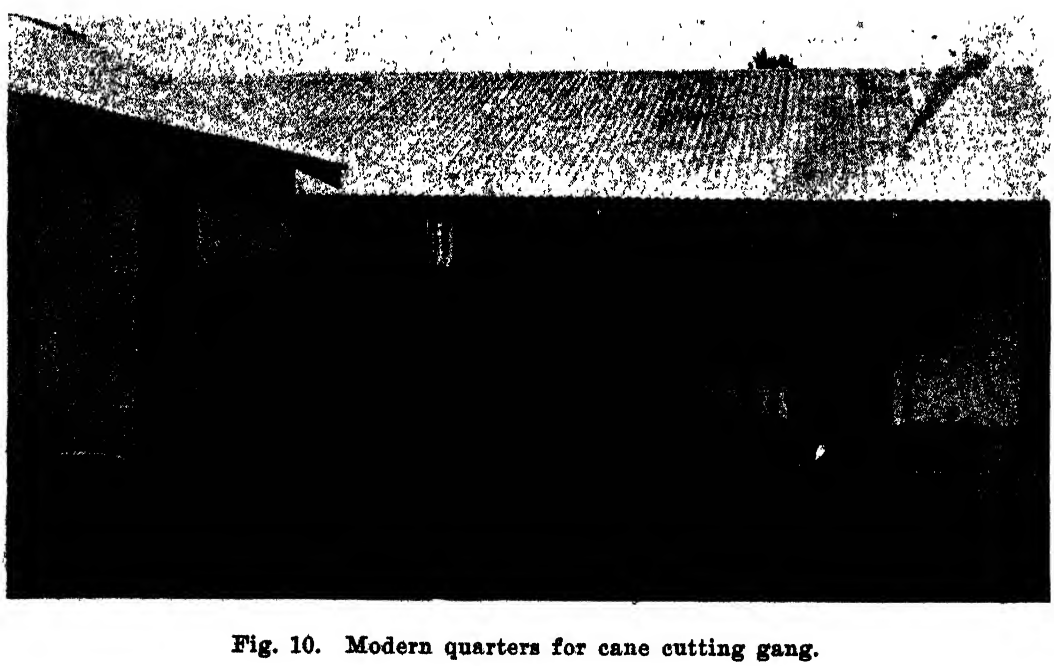


Fig. 10. Modern quarters for cane cutting gang.

General: There is very little control in the milling practices, because other than weighing cane in and sugar out, few weights are taken. Thus the milling losses are undeterminable and the extraction figures only approximate. It was of interest to note that some of the laboratories were using the same laboratory forms they used 30 years ago.

Factories are steam or belt driven, none electrically driven although some parts may be. There are few safety devices in the mills, open gears and belts are common, and the amount of belting appears excessive. However, there are very few accidents in the mills which may probably be due to the high type of intelligence of the labor.

Conclusion: In conclusion, we must admit we found little in the Australian field practice that we feel can be adopted in Hawaii to help us grow cheaper sugar. Their preparation for planting appears to be excessively overdone, and we question the necessity of planting cane in deep furrows on the unirrigated lands. Their irrigation methods appear wasteful of water, and it would seem that there is room for larger cooperative pumping units to replace the many individual units now operating. Their fertilizer program needs to be differentiated on the basis of proven facts of their soil fertility needs, and when found, such facts need recognition. As with their preparation, cultivation also appears excessive, and poor stands, small stools, and failure of ratoons, all indicate that something may be wrong with their cultivation practices.

One comment was, "they worry the cane to death with their continuous use of implements." Another was that, "the machinery salesman must have found the Queensland sugar district a paradise in which to sell," and "since the farmer has bought all these implements, he feels that he must use them whether or not he needs to." Their harvesting is efficient but perhaps no more so than ours, and it is certainly more expensive.

Their cane farmers are not all happy and prosperous. Their homes are too often without the modern conveniences of running water and sanitary facilities. Few own automobiles, and recreational facilities except the race tracks are sadly lacking. Their highly paid laborers are always "broke" after their week end in town. They live in very unattractive barracks on the farms. The high standard of living these laborers enjoy was not prominently demonstrated unless the Saturday night crowd in the "pubs" exemplifies this high living.

The fact that the elaborate system of government control does not obviate expensive strikes (labor troubles) was well illustrated by the strike of cane cutters in progress as we visited the Tully district; hundreds of cars of loaded cane were left rotting in the mill yard while the government refused to step in and settle the illegally called and prolonged strike that was on. Likewise we note that the government's 1929 attempt to restrict the sugar crop to the domestic market has not reduced production, as seen by the fact that their 1934 crop was nearly 20 per cent larger than their 1929 or the 1930 crop.

Hence, other than their policy and practice for controlling cane diseases, which appears economically sound and definitely effective, the Australian sugar industry has little that the Hawaiian sugar planter might adopt in his efforts to grow cheaper sugar.

Growth-Failure Problems

By A. J. MANGELSDORF

The so-called growth-failure areas on our plantations merit attention not only because of the loss in sugar yield which they entail but especially because they may represent in an exaggerated form the effects of plant food deficiencies, of toxins, or of other depressing factors which are acting upon larger areas in a less pronounced degree. As such, they provide research material for a study of growth factors which might prove elusive under more nearly normal conditions.

Such interest is not necessarily applicable to all areas of poor cane growth. Many of the poor-growth spots are of local significance only. An example of the latter type is the growth failure in Fields Mill 3 and 5, Waialua, found by J. P. Martin* to be due to the shallowness of the soil overlying an irregular stratum of coral rock. Similar examples of growth failure due to shallow soil and rock outcroppings may be found at Ewa; in the island fields of Oahu Sugar Company, Ltd., and in the Puuloa fields of Honolulu Plantation Company.

Other growth-failure spots of local significance only are the following:

1. Small areas of poor growth at Kilauea, on spots where carloads of coral sand were dumped in past years.

2. Areas of poor growth due to high salt content, such as the saline spots near the sea at Kekaha; in the Puuloa fields of Honolulu Plantation Company; and in the makai fields of Olowalu Section, Pioneer Mill Company, Ltd.

3. Gravelly areas of low moisture-holding capacity in certain of the Olowalu fields of Pioneer Mill Company, Ltd.; and at the Mapulehu Station on Molokai.

4. Coral chlorosis areas. The problem of supplying iron as a soil amendment remains unsolved. A trial of briquettes containing iron salts has been suggested.

Other growth-failure areas, the causes of which have not been fully established, and which therefore demand further attention include the following:

1. Areas of relatively poor growth in the older mauka lands of McBryde and Makaweli as contrasted with the superior growth on immediately adjoining virgin land which has recently been added to the field. Studies of the differences between closely adjoining areas of new and old land would appear to offer particular interest. Such studies might be expected to throw light on the cumulative effect, if any, of years of irrigation, fertilization, and cropping and perhaps to forecast further changes to be expected as cropping is continued. While it is true that the yields in sugar per acre per month over the Territory as a whole have been increasing, the superior growth of cane on new lands as at McBryde and Makaweli serves to remind us that the improvement in yields realized in the past does not establish the absence of a downward trend in one or more of the essential growth factors, but merely that improvements in other respects have more than offset the effect of such downward trends if they exist.

* *The Hawaiian Planters' Record,* Vol. XXXII, 1928, pp. 406-411.

It is to be expected that in the course of time a limit will be reached in the gains to be effected by improved agricultural practices and more vigorous cane varieties. Considerable interest therefore lies in the question of whether the soil is being impaired in any way, and if so, how the impairment is to be met. Investigations comparing the cane and the soils of adjoining areas of new and old land would appear to offer a promising approach to this problem. What differences, for example, are to be found between the old and the new lands in available P and K and in the other essential elements? What has been the effect on the colloidal fraction of years of irrigation at a rate equivalent to one or two hundred inches of rainfall a year?

2. The Maui "H 109 Growth-Failure Areas." These areas have received considerable attention during the past five years. In cooperation with Hawaiian Commercial & Sugar Co., Ltd., O. H. Lyman has carried out a number of pot tests with indicator plants in which many soil amendments have been tried. Treatments which gave indications of benefit were subsequently tried on affected cane in the field.

The treatments have included nitrogen, potash, and phosphorus in various forms and amounts as well as such soil amendments as molasses, press cake, agricultural lime, chloropicrin, sulphur, portland cement, barium chloride, copper sulphate, manganous sulphate, ferrous sulphate, calcium chloride, potassium iodide, sodium borate, potassium bromide, zinc sulphate, pyrogallol, and silica (waterglass).

Heavy applications of phosphate have resulted in improved growth in the pot tests, in spite of the fact that available P as determined by kit and citric soluble analyses is higher in the growth-failure areas than in the normal soils. This suggests a possibility that the phosphate applications exert their effect indirectly, perhaps by precipitating some toxic material, such as aluminum.

In 1925 W. T. McGeorge found evidence of iron or aluminum accumulations in cane from Maui growth-failure areas, but subsequent studies by him in 1926 failed to substantiate his original findings.

In 1934 D. A. Cooke conducted a study of normal and growth-failure soils from Field 2-G, Co. 9, Hawaiian Commercial & Sugar Company, Ltd. His findings indicated that active aluminum is responsible for the growth-failure, and that the beneficial effect of applications of phosphate and filter cake are due to the action of these materials in converting toxic aluminum to insoluble and harmless forms.

The results of analyses of these soils by the Chemistry department are tabulated below. The figures show that while P_2O_5 is higher in the growth-failure soils than in the normal soils, aluminum is also higher. The high alkalinity of the growth-failure subsoil is characteristic of such areas.

It has been suggested that magnesium toxicity, or high magnesium in proportion to calcium may be responsible for the Maui growth-failure symptoms. These analyses, however, are not in agreement with this hypothesis.

HAWAIIAN COMMERCIAL & SUGAR CO., LTD.

(Field 2G, Co. 9)

(Results calculated to water-free basis)

Lab. No.	Mitsch. No.	Reaction pH	1% Citric Acid Soluble SiO_2	CaO	K_2O	P_2O_5	Fe_2O_3	MnO_2	Al
Growth-failure—first foot									
623	1211	8.1	1.550	0.824	.1279	.0481	1.051	0.100	.394
Growth-failure—second foot									
624	1212	8.8	2.482	1.155	.1241	.0414	1.338	0.105	.520
Normal—first foot									
625	1213	8.1	0.822	0.508	.1033	.0144	0.520	0.149	.268
Normal—second foot									
626	1214	7.8	0.643	0.489	.0806	.0177	0.374	0.113	.273

Lab. No.	Mitsch. No.	Replaceable CaO	MgO	Na	Water Sol. Solids	Kit P_2O_5	P_2O_5 Fixation Index
Growth-failure—first foot							
623	1211	.242	.130	.089	.072	High	10
Growth-failure—second foot							
624	1212	.344	.086	.061	.106	High	0
Normal—first foot							
625	1213	.248	.164	.087	.075	High	30
Normal—second foot							
626	1214	.262	.153	.085	.097	High	40

Mr. Cooke's suggestion that the Maui growth-failure symptoms are due to aluminum toxicity would appear to merit further investigation. It would be of particular interest to determine whether the chlorotic leaf streaking which characterizes the cane in growth-failure areas can be induced on cane plants in pot cultures by additions of aluminates to normal soil under alkaline conditions.

The following is an excerpt from Mr. Lyman's annual report for 1934:

One pot test with H 109 growth-failure soil was carried on cooperatively with Maui Agricultural Company and Hawaiian Commercial and Sugar Company. In this test, growth-failure soil was diluted with good soil ranging from 0 to 100 per cent with 25 per cent increments. Surface and subsoils were run separately. Practically no difference was found in the yields from surface or subsoil, but with both when the better soil was added, the yield was heavier. From these results we believe the problem has been narrowed down to either a lack of some plant food or an oversupply of a toxic substance in the soil.

Several tests were made with iron sulphate spray on growth-failure cane in Field 19 at Hawaiian Commercial and Sugar Company. One area produced a decided greening from the iron application but subsequent spraying on nearby areas revealed no greening from this addition.

Repeated tests with factory mud have shown definite and good response in growth-failure areas. So far this is the only material of any kind that has produced a response in this field. We are now cooperating with the Chemistry department with the hope of determining just what it is in the mud that produces this response.

Mr. Lyman discusses the present status of the problem in a recent report to R. J. Borden as follows:

In reply to your memorandum concerning growth failure on Maui, project A-103, our studies have been limited to the special type commonly known as "H 109 growth-failure," confined entirely to H. C. & S. Co. and M. A. Co. and chiefly to the former. Other growth-failure areas on the Island are of minor importance or may be described as gravel pockets or have some obvious cause. These will not be taken up in this report, where we will confine ourselves to "the H 109 growth-failure" areas located in Central Maui.

Characteristics of the Malady

The first appearance of the malady is an irregular chlorosis of the central portion of the leaf. In the early stages or in mild cases the outer edges will retain their green color. More severe cases become chlorotic throughout. Brown stripe disease is usually found in great abundance showing the most marked infection on the older lands. Cane grown on failure spots in virgin soil is relatively less susceptible to brown stripe than on the older areas. The failure symptoms may first appear in knee-high cane, cane in the boom stage, or not until the crop is partially matured.

Stunting of the entire plant follows the first symptoms and in extreme cases the stool will die out entirely. Stools may be pulled out of the ground with ease, exposing roots badly diseased and some entirely decayed. *Pythium* has been found by our pathologists but is usually considered as a secondary infection.

Soil Characteristics

Generally speaking, in old lands little difference may be found in the physical appearance or chemical composition of the soil in the failure areas when compared to good areas in close proximation. However, in virgin lands where a dark purplish subsoil is found close to the surface, the growth-failure malady is found to accompany it. Also in areas where a peculiar whitish-grey rotten rock is found outcropping, the disease may usually be found.

Work Done So Far In Search of a Remedy

Chemical analysis, pot work, and field experimentation have been carried on on a large scale for many years in an endeavor to locate some clue that might give us a remedy. To date but two lines of attack appear successful, i. e., factory mud applications and more resistant varieties. Factory mud has given marked responses where all other soil amendments failed. Complete analyses are now under way in an effort to determine the exact composition of this material so that we may find the single ingredient or series of ingredients that will satisfy the requirements, i. e., either precipitate the toxins or supply some deficiency that growth may be maintained.

From the variety standpoint the very leafy vigorous canes appear to withstand the malady. In recent harvests Co. 290 and 28-4314 have proved the most resistant. 30-2417 although not as extensively tested as the two previously mentioned, appears promising.

Increase or Decrease in Extent of Areas

There has been much discussion as to the possible increase or decrease in the size of the individual growth-failure areas. A great deal of time was spent in cooperation with the plantation civil engineering department of H. C. & S. Co. to obtain definite information on this controversial question. All of the fields which today are known to possess areas of this malady were studied in detail as far back as 1909 and 1910. It was found that in most cases when a field was planted the entire area was plowed up and planted to cane. When these failure spots became evident they were culled out, dropped from cultivation, and the location and area recorded on the original map in the engineer's office. At the start of each succeeding crop the field was subjected to this procedure and as a consequence we have a record of the areas discarded for many years back.

It must be remembered, however, that these areas removed from cultivation contained gravel pockets, sand pits, etc., in addition to the typical "H 109 growth-failure areas." But should the "H 109 growth-failure areas" be slowly increasing in area many of these spots would be recorded as gradually increasing in size over the period of time (25 years) in which the study was made and today would have reached a size much greater than that originally recorded. This, however, cannot be found on the maps. A few areas have increased in size, others have decreased, and still others have disappeared entirely. We therefore could find no proof that the areas are definitely becoming larger.

From the personal observation of the writer during the past seven years, certain fields which have shown marked infection in the plant crop, have produced a decreased degree of infection as crops go on in that planting cycle; other fields show that new areas have sprung up which were never before known to the oldest man on the place; others have maintained uniform size not varying from crop to crop; and still others have increased in size from time to time.

Records of the exact location and extent of these areas are still being continued by the engineering departments of both H. C. & S. Co. and M. A. Co.

The tolerance of Co. 290 and certain other seedlings for the growth-failure condition is of interest from the plantation standpoint, but it throws no light on the cause of the failure in the case of H 109.

As Mr. Lyman has suggested, the effectiveness of press cake in correcting the difficulty should provide clues which may lead to an understanding of the underlying causes; these clues need to be pursued further.

3. Hamakua Growth-Failure. The interest in the low-yielding fields of mauka Kukaiau (Hamakua Mill Company) finds justification in the premise that if ways and means can be found to improve the yields of these fields the findings may have rather wide applicability in the mauka lands of the Hilo, Hamakua, and Kohala districts.

Under the late Y. Kutsunai's supervision the problem was attacked from many angles. Mr. Kutsunai's daily reports (Project File 452.11) give detailed accounts of the various phases of the investigation. Summaries of the work appear in the annual reports of the Agricultural department for 1933 and 1934. The subjects to which attention was given included the following:

1. Phosphate fixation.
2. Loss of nitrogen and potash by leaching.
3. Moisture-holding capacity of the soil.
4. *Pythium* injury to the roots.
5. Accumulation of iron and aluminum at the nodes.
6. Amounts and forms of N, P, and K.
7. Methods of applying N, P, and K.
8. Effects of other essential elements and of various soil amendments.

The findings may be summarized as follows:

1. The growth-failure soils were found to be low in available P and K.
2. Phosphate fixation, at first believed to be extremely high, now proves to be only moderately high.
3. Potash and nitrate nitrogen are readily leached.
4. Moisture equivalent determinations have given anomalous results, and require further study.

5. *Pythium* injury to the roots was shown to be an important depressing factor in pot studies on these soils. Heavy applications of phosphate, even in the presence of *Pythium*, resulted in normal growth in the pots. Are the severe *Pythium* damage and its amelioration by applications of phosphate peculiar to pot cultures as contrasted with cane growing in the field? (The tremendous responses to phosphate regularly obtained in pot tests with canes as well as with Sudan grass have not been realized from cane growing in the field.)

6. Accumulations of iron and aluminum were found at the nodes of cane plants from the affected areas. What importance is to be attached to these accumulations?

7. Except for N, P, and K, cane leaf compost (heavily fertilized with N, P, and K during composting) and stable manure, none of the soil amendments has proved effective in improving cane growth.

A possible exception to the above is lime. Recent pot tests on Sudan grass growing in the Hamakua soils show response to calcium. Is Sudan grass a lime-loving plant as compared with sugar cane?

The most satisfactory cane growth attained thus far on these poor soils is to be seen in an observation test in Field 27 Kukaiau (Indicator Test No. 39). The variety is 28-4291, a Uba-H 456 seedling which has been among the leaders at the Hamakua Mauka Variety Station. Various amounts of N, P, and K were tried on small plots of this seedling. Of the three elements, nitrogen appears to have been the most effective, a marked response having resulted from a 500-pound application of N. Heavy phosphate applications in addition to the 500 pounds of nitrogen resulted in further gains.

The growth response in this observation test suggested to Mr. Kutsunai the desirability of a replicated experiment to determine the ability of 28-4291 to respond to various amounts of N, P, and K. Shortly before his death he arranged for the planting of a seed nursery of 28-4291 at Paauilo for the purpose of obtaining planting material for the installation of further fertilizer tests on this variety in an abandoned growth-failure portion of Field 27 Kukaiau. These tests are now under way.

The mauka lands of Honokaa which formerly gave poor yields have been brought to a satisfactory level of productivity. H. P. Agee suggests a comparative study by rapid chemical methods of Kukaiau versus Honokaa soils to determine the differences, if any, between the two. Mr. Borden suggests further that virgin uncultivated soils of each series be included in the study.

It would seem desirable to compare the Honokaa and Kukaiau soils in pot tests also, on the chance that there may be differences between the two which might escape detection by chemical methods.

4. Areas of poor growth on the upper lands of windward Kauai. Mention has already been made of small growth-failure spots at Kilauea where carloads of coral sand had been dumped in the past. Greater interest, however, attaches to the more extensive areas of unsatisfactory growth on the middle and upper lands of the windward plantations. The cane on these poor areas is characterized by freckled, chlorotic leaves and by severe brown stripe infection. Apparently, however, these are merely symptoms rather than causes of the poor growth.

In 1932 Arthur Ayres investigated the soils of some of the poor mauka fields on windward Kauai. He describes these soils as follows:

1. Surface soil shallow.
2. Lime content low, magnesium probably also low.
3. Reaction moderately to highly acid.
4. Low in phosphate, potash, and silica.
5. Phosphate fixation high.
6. Subsoil highly acid and infertile.

As regards climate, the Kauai growth-failure areas have nothing in common with the "H 109 growth-failure areas" of central Maui, yet they are both marked by severe brown stripe infection, a circumstance which suggests that these two widely different soil types may have some toxic element in common. The fact that they both respond to phosphate applications in pot cultures emphasizes their relationship. Do phosphate applications exert their beneficial effect on both of these soils by precipitating toxic aluminum and rendering it inactive?

Dr. Constance Hartt has recently grown plants in cultures lacking magnesium. These plants show leaf symptoms closely resembling the Kauai growth-failure symptoms except for the absence of brown stripe, due perhaps to the absence of sources of infection.

Observation tests with magnesium sulphate were suggested by W. W. G. Moir in 1931 and several tests were subsequently installed in the Makee Section. On the whole, the response in cane growth in these tests was not definite. Nevertheless, it would seem desirable to repeat tests of a similar nature on the growth-failure areas using magnesium, alone and in combination with calcium in varying proportions.

Whatever the causal factors may be, these growth-failure areas with their high incidence of brown stripe present an interesting riddle—one which thus far has defied the many attempts to solve it, and which for that reason offers a tempting challenge to the investigator.

Summary

1. The so-called growth-failure areas are of special interest as subjects for research because they may represent in an exaggerated form the effects of depressing factors which are active in a milder degree over large areas and which, in their milder manifestations, may elude analysis.

2. Among the problems related to growth failure which still remain to be solved are the following:

a. What factors are responsible for the superior growth of cane frequently noted on virgin lands which have been recently added to old fields by extending their boundaries?

b. How can iron best be supplied to chlorotic cane on alkaline coral soils?

c. New varieties having a high degree of tolerance for both the Maui and the Hawaii growth-failure areas are now available. What are the deleterious factors to which these varieties are resistant and what is the nature of their resistance?

d. What factors are responsible for the high incidence of brown stripe disease on the growth-failure area of windward Kauai?

The work which has already been done on the growth-failure soils has added a great deal of information, but the underlying causes of the poor growth on these soils are not yet fully understood.

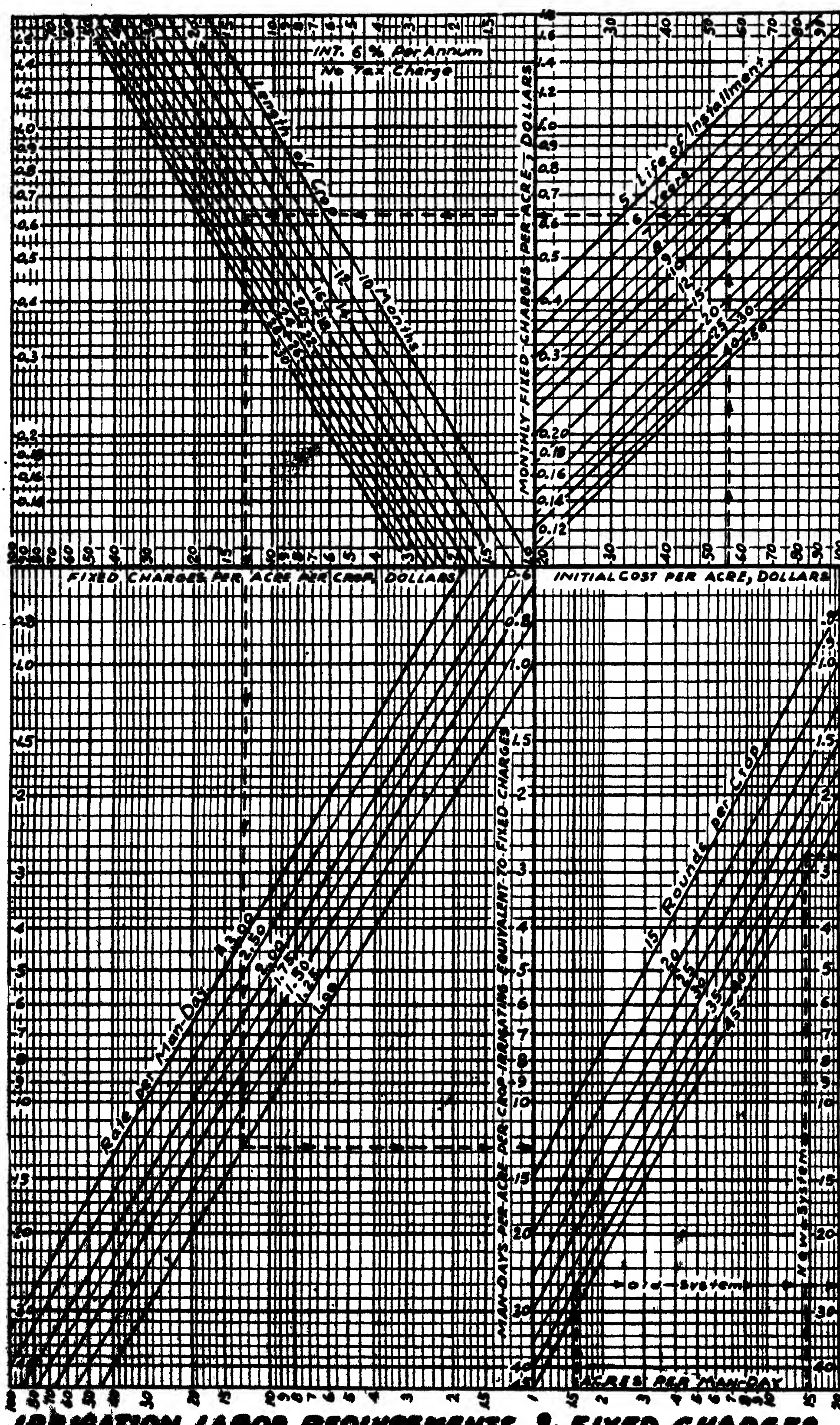
Irrigation Labor Requirements and Fixed Charges

By W. W. G. Moir

During the last few years considerable interest has been shown in the reduction of labor requirements for irrigation. The reports of the Hawaiian Sugar Planters' Association and the Association of Hawaiian Sugar Technologists have shown the various changes that have been made in irrigation procedure to speed up irrigating and lower costs. The newer systems have greatly increased the area per man-day covered in irrigating. Most of these newer systems have been developed on slightly sloping or fairly flat lands, where the grades of the cane line and the supply ditches or level ditches have been such that speed could be attained without excessive erosion or decreased growth of cane. The steeper slopes, however, have been left in the old contour systems or the various improvements of it, such as the Koloa system, the hulihuli or others. These improvements of the contour system, even to the long-line contour have not attained the acreage per man-day that has been obtained on the border and straight-line systems of the slighter slopes and flat lands. This has been due entirely to the size of the stream that could be brought down the steeper grades to feed these lines. Watercourses, straight ditches, wing ditches, or even the zigzag "level" ditches of the Pioneer system were subject to too much erosion whenever the rate of irrigating was increased by using larger volumes of water.

To correct this drawback and to put these steeper slopes on an equal footing with the other lands, a number of plantations have developed systems using permanent or semi-permanent installations. These have taken care of all erosion and have permitted the irrigator to cover as much as, or more than, the area per man-day obtained on the slighter slopes with the long-line or the border systems. These permanent or semi-permanent installations have been of various types, such as: the wooden structures of the Baldwin* flume type, the concrete flumes and ditches of a semi-permanent nature like that at Waialua, the permanent ditches of rubble or cut stone and concrete, the cocnrete pipe and straight ditches at Pioneer, and several others.

* Mr. Washburn Baldwin has recently developed a new type of concrete flume, a model of which may be seen at the Experiment Station.



IRRIGATION LABOR REQUIREMENTS & FIXED CHARGES

It is only natural, therefore, that before such permanent or semi-permanent installations are made the various factors in each cane field which would influence the economy of making the installation should be studied. The amount that can be expended upon the initial installation will be dependent upon many factors. In this article, however, the matter of fixed charges resulting from the interest on the money invested and the depreciation of the structure are utilized to draw up a chart which may be useful to field men in their study of the particular installation contemplated. Taxes and insurance are not considered in these figures as they are too variable and would complicate the problem.

Therefore, the various factors entering the problem of whether the installation will be economical or not are, besides the initial cost, as follows:

1. The life of the installation or years in which it will be depreciated on the books.
2. The monthly fixed charges at 6 per cent interest on the money invested computed from the depreciation taken on the installation and the initial cost.
3. The length of crop in months.
4. The basic wage you expect your irrigator to make in the field.
5. The average acres per man-day required to irrigate the present system and what will be expected on the new.
6. The number of rounds of irrigation in the field for the crop.

The life of the installation will be dependent upon the material used, the length of lease on the land if not fee simple, the governmental tax rulings and the chances of the system becoming obsolete.

The fixed charges will be figured on the initial cost, the rate of interest per annum and life of the unit. As mentioned above, the taxes and insurance are not included here. The various formulae and calculations used in setting up the chart as far as fixed charges are concerned are explained herewith:

P—initial cost of installation per acre.

R—rate of interest per annum (6 per cent in this case).

n—life of the installation.

(1) Interest $= P \times R$

(2) Annual depreciation $= P\left[\dfrac{R}{(1+R)^n - 1}\right]$

Therefore, without taxes, insurance, rent, etc., the annual fixed charges would be the sum of (1) and (2).

(3) Annual fixed charges $= PR + P\left[\dfrac{R}{(1+R)^n - 1}\right]$ which equals

$$P\left[\frac{R}{1-\left(\frac{1}{1+R}\right)^n}\right]$$

The monthly fixed charges used in the chart are one-twelfth of the annual charge.

In the chart the initial costs have been varied from \$20.00 to \$100.00 per acre and the life of the installation from five to fifty years. It is quite conceivable that these figures may be more or less than those used, but these were decided upon as

covering the average condition. There are conditions, however, in which an initial cost as high as $150.00 per acre might become economically worthwhile.

The other items in the chart have been varied as follows:

Monthly fixed charges	$0.10 to $1.80
Length of crop	10 to 30 months
Crop fixed charges	$1.00 to $100.00
Basic wage	$1.00 to $3.00 per day
Rounds of irrigation	15 to 45
Acres per man-day	1 to 20
Man-days per acre per crop and Man-days per crop equivalent to fixed charges	0.6 to 4.5

Most of these are clear enough without any further explanation. The basic wage item, however, is a figure obtained by considering the irrigation contract rate, the cane tonnage per acre and the days worked in the contract. In many of these newer systems the rate has been lowered because of greater coverage per man-day and because weeding has been eliminated from the work performed by the irrigator. The example used of $1.00 per day is very low considering the average of all plantations but the figure was used to show an extreme number of days that would have to be saved to be equivalent to the fixed charges per crop.

As a means of explaining the working of the chart, let us follow the dotted line given as an example on the chart. The data used are:

Initial cost per acre	$56.00
Life of installation	10 years
Length of crop	20 months
Rate of wage per man-day	$1.00
Rounds per crop	40
Acres per man-day old system	1.55
Acres per man-day new system	14.5

Beginning on the lower edge of the upper right section of the chart with the figure $56.00, follow the dotted line to where it intersects the oblique 10-year line, then proceed at right angles to the left until the dotted line crosses the vertical scale. Here you can read the figure representing the monthly fixed charges per acre which, for this example, is $0.63+ per acre per month.

Continuing on the same dotted line to the left to where it intersects the oblique length of crop line representing 20 months and then at right angles down the chart to the horizontal scale, you obtain the fixed charges per acre per crop, which is approximately $12.60 in the example.

Proceeding on into the lower left section of the chart with the dotted line to its intersection with the oblique $1.00-per-day line and at right angles to the right to the vertical scale, we obtain the man-days per acre per crop equivalent to the fixed charges, which is 12.6 men. As mentioned above, the $1.00 per day is low and shows an extreme number of men necessary to be equivalent to the fixed charges. This represents the number of man-days that must be saved during the crop to at least pay for these fixed charges on the installation.

To see how your present irrigation system and the new one contemplated would allow for such a saving, we start again in the lower right section with the acres per

man-day covered in irrigation. The old system starting with its 1.55 acres per man-day and going up to the oblique 40-rounds line, and then to the right, shows that it would require just under 26 man-days to irrigate the crop. The newer system with its 14.5 acres per man-day and the same 40 rounds would require but a little over 2.75 man-days to complete the crop, as is shown by following the other dotted line starting at 14.5 going up to 40 and across to the right.

The difference between the 26 and the 2.75 man-days per acre per crop would be sufficiently great to fully cover the equivalent man-days per acre per crop for fixed charges of 12.6 obtained in the other three sections of the chart and which has been explained above.

By changing the daily wage to $1.50 and the rounds to 15 per crop and leaving all other things the same, the fixed charges per crop in equivalent man-days would equal the difference between the new and old systems on 15 rounds.

By increasing the daily wage the irrigator is expected to make the equivalnt man-days to pay for the fixed charges decreases. But other factors must change as well to keep the final cost of sugar per ton from increasing. But in the future, if labor becomes scarcer or more costly, these permanent installations will show even greater savings.

It must be remembered at this point that these are purely the considerations for the payment of the fixed charges due to the initial cost as explained above. Naturally, with increased coverage per acre per man-day the labor requirements of the plantation for irrigation purposes will be decreased and this will have its reducing effect on overhead charges for housing, hospitalization, etc.

Almost any section of this chart can be utilized separately to obtain necessary information about other operations on the plantation. The upper right-hand section can show you the fixed charges per month on almost any type of structure at the various costs per unit and per years of depreciation.

The lower right-hand section can show you just how little an increase in acreage covered per man-day will give a very substantial decrease in costs of irrigating the crop.

All spacings and lines have been made on a logarithmic scale, so, when determining the approximate reading, judge the space accordingly. By a study of the spacings on the various scales of the chart, you may readily get an idea of how to divide up spaces when necessary.

The writer is indebted to John Okamoto, of the Engineering Department of American Factors, Limited, for the assistance rendered in making the necessary computations and setting up the chart.

Investigations on *Anomala Orientalis* Waterhouse at Oahu Sugar Company, Ltd.

By F. A. BIANCHI

The Asiatic beetle, *Anomala orientalis* Waterhouse, was probably introduced into Hawaii from Japan at some time prior to 1908. This beetle is not known as a pest of sugar cane in its native habitat, and in Connecticut where it has also been introduced, is found exclusively as an inhabitant and destroyer of lawns; but in Hawaii it has established itself as one of sugar cane's most important enemies. Although not yet spread to any other island than Oahu, and found here only over a relatively small area of 14,000 or 16,000 acres, the ravages of Anomala have at times been so serious as to cause the taking of extensive measures to combat it.

Many thousands of dollars were spent in devising means of artificial control and in seeking effective parasites during the early years of Anomala's spread, but without success. Finally, in 1916 and 1917, relief followed the introduction of a parasite. This parasite, *Scolia manilae* Ashmead, the wasp now so well known to plantation men, was at that time introduced from the Philippine Islands with such pronounced results that shortly after its introduction grubs and beetles actually became difficult to find in the previously heavily infested areas, and, with the exception of one or two minor cases, no further damage to cane was reported until early in 1930. At that time the harvest in two different fields of the Oahu Sugar Company, Ltd., again showed a considerable drop in production, attributable only to damage done by Anomala larvae which were to be found in the soil in greater numbers than at any time since the introduction of *Scolia manilae.*

For some time entomologists were of the opinion that the renewed abundance of the beetle might represent one of the occasional outbreaks, usually of short duration, which can be expected even under the best conditions of biological control. Eventually, however, when following harvests disclosed other limited areas of severe damage and a generally greater abundance of *Anomala orientalis* than had been usual for several years, it became evident that a careful investigation of the increase of the beetle was necessary, as it must have been due to a more permanent disturbance of the balance of pest and parasite than was to be expected under the usual course of nature. Subsequently, the conduct of that investigation became one of the major projects of the Entomology department of the Experiment Station, H.S.P.A.; and to facilitate much of the necessary work, the writer was detailed to take up permanent residence on the plantation of the Oahu Sugar Company, Ltd,, there to devote full time to the study of the problem.

In the opinion of entomologists, one aspect of the problem involved a careful study, with an eye to possible reappraisal, of the biological factors of the Scolia-Anomala complex; a study which heretofore had only been carried on in a more or less desultory manner. To that part of the work then, the writer mainly directed his efforts and although the many ramifications of the problem will require much more thorough and lengthy investigation than has yet been given, it is hoped that the

results presented here will not prove entirely without value or interest to plantation men and other workers along the same line.

Life History of Anomala in the Field

It is hardly possible to determine accurately how well figures obtained in the laboratory represent the life cycle of Anomala in the field. A repetition, of certain general tendencies observed in the laboratory, towards a wide range of variation in larval life lengths, and towards a shortening of the life cycle during the warmer months of the year for example, is to be expected, and as a matter of fact is shown by all our observations; but the nature of the infestations makes it impossible to accumulate unmistakable quantitative data in corroboration of these and other points. The work so far done on the problem, however, gives us a satisfactory working outline of the picture, only the details of which are apt to be modified by further study.

Oviposition:

Under the usual field conditions, where the soil surface is dry and all but the upper layer is more or less packed, oviposition may occur at any depth to 18 inches, but eggs thus scattered through several inches of soil are so hard to find as to lead to the conclusion that because of difficulty experienced by beetles in ovipositing in hard soil, or because of great natural mortality of the eggs themselves in such a medium, they are actually scarce. Because of this scarcity it has been impossible to gather sufficient quantitative data to determine just how oviposition is distributed through this zone, but the impression that one gets in the absence of trash or mud press mats providing ideal conditions near the surface, is that most eggs are to be found between 6 and 12 inches deep, being much scarcer at lower soil levels. In recently harvested fields, however, it often happens as a result of poor "burns" that large areas of the field remain covered with a mat of cane trash and, if rainfall at the time is sufficient to keep the trash from drying out too much, oviposition seems to become concentrated at the point of contact of soil and trash. Eggs then are easily found and, apparently at least, are far more abundant than under ordinary conditions. Concentration of oviposition is also an ordinary occurrence in and under the crust of mud press which forms over the surface of the soil in fields where this material is sluiced on as fertilizer in irrigation water. In these cases accumulations of eggs are likely to be short-lived among the cane itself, because of their early destruction by the various processes of cultivation, but they often last long enough to produce a good many beetles in the various sorts of ditches, with which every field is provided, where mud press settles in large amounts and may remain undisturbed for weeks at a time.

A point which has not been determined is whether or not accumulations of eggs occur partly in consequence of some special attraction of trash and mud press for the ovipositing beetles or solely as a result of favorable conditions which cause a larger proportion of egg survival than is usual; but the latter of these explanations appears to be the more reasonable one, as beetles are very often found burrowing into dry soil, often in dry ditch bottoms, in evident disdain of more propitious locations within the immediate vicinity.

One might be inclined to believe that more eggs are found among or near the cane stools than between rows, but this is not necessarily the case. That eggs and grubs are more often looked for near the cane stools is true; but, as a matter of fact, the occasional trash accumulations under which they reach the maximum abundance lie very often between the rows, i. e., in the *pali pali,* or raked up trash.

All our observations show that mating and oviposition take place within a small radius of the point where the female beetle emerges. Distinctly fresh females carrying a full complement of eggs, and either single or in copulo, are very often found on the surface of the soil or among trash, but only within crawling distance of infested stools. Beyond this distance neither the writer nor anyone he has heard of has ever found them, either crawling or flying; all those so found, or feeding on flowers, being old, and retaining only a part, if any, of their original egg supply. A single example, from among the many records upon which this conclusion is based, shows that out of a total of 126 adult females caught on flowers by O. H. Swezey on May 2 and 6 of 1913, 123 contained no eggs at all, 2 contained one egg each, and one contained 14 eggs. More recently the writer in the course of one afternoon gathered more than 200 beetles, on flowers of *Leucaena glauca,* of which the one containing the largest number of eggs had only eight.

Observations made in Hawaii, where empty or nearly empty females are often caught in copulo on the flower heads of *Leucaena glauca,* agree with those of E. W. Friend in Connecticut, that more than one mating may take place; but whether any but the first is essential to the oviposition and fertilization of all the eggs has not been determined. However, if a second mating is necessary, the fact that it often does occur explains how females with only a residue of their original egg content might be entirely accountable for the spread of the pest, a supposition which agrees well with the obviously slow rate at which this spread has taken place.

As a whole, the manner and amount of oviposition in the laboratory lay fairly constantly within limits not far distant from the mode. Occasionally, nevertheless, these were widely overlapped. Table I shows the records of 16 females reared in the laboratory, and for comparison Table II shows those of ten females collected soon after emergence in the field. Eggs are laid by day and by night, sometimes singly, but as a rule in batches of from 2 to 12 with intervals usually of a day or two, and often longer, between successive batches. The average lies between 5 and 7 eggs per batch; the recorded maximum being 24. The total number of eggs produced by one female, including a small per cent which, as appears later, is sometimes not laid, averages 30 or 40. Occasionally this number mounts to 50 or 70, and in a single instance recorded in our files by O. H. Swezey, reached a surprising maximum of 103 eggs, including those retained in the ovaries after death. Considerable difference seems to exist between insectary-reared and field material in this respect. As a comparison of Tables I and II shows, the average for 16 reared females was 30 eggs, or 11 eggs less than the average obtained from 8 females collected in the field. This difference becomes more significant considering the uncertainty that females collected in the field had not already laid some of their eggs.

Neither males nor females are ready to undertake their natural functions immediately upon emergence from the pupal stage. It takes about a day for the chitinous integuments to harden, and a somewhat longer time for the internal physiological

adaptations necessary before mating takes place. The interval of time between emergence from the pupa and the first copulation is very likely to vary widely. In at least one case a female copulated and laid her first batch of eggs within 24 hours of emergence from the pupa. In most cases 3 or 4 days pass before mating will take place even between a male and female placed in a small container and jostled together. Such jostling of fresh males with each female as soon as her integuments hardened sufficiently after emergence was the procedure followed in every one of the 16 cases given in Table I; and the average length of this interval of development for 12 laboratory-reared females was 4.5 days, as shown in the last column of the table.

TABLE I

Number	Date of emergence	Date of death	Days alive	Dates and number of eggs laid in each batch (Number of eggs given in parenthesis)	Total No. of egg hatches	Total of eggs laid	Average No. of eggs per batch	Eggs contained in body after death	Potential total of eggs	Date of first copulation	No. of days from first cop. to oviposition	No. of days from emergence from pupa to oviposition	No. of days from emergence to first copulation
1	1/14	1/30	16	1/19(9) 1/21(7) 1/22(?) 1/23(?) 1/26(11) 1/28(4) 1/29(1)	7	40	6—	0	40	?	?	5	?
2	1/29	2/17	20	2/9(5) 2/11(1) 2/13(1) 2/14(5) 2/15(5)	5	17	3+	6	23	2/4	5	11	6
3	2/17	3/4	15	2/18(4) 2/22(3) 2/26(2) 2/27(2) 2/28(3) 3/1(5) 3/2(6) 3/3(1)	8	26	3+	0	26	?	?	1	?
4	2/17	3/4	15	2/21(11) 2/22(5) 2/23(3) 2/24(6) 2/25(1) 2/26(2) 2/27(3) 2/28(1)	8	32	4	2	34	2/20	1	4	3
5	3/1	3/16	15	3/15(6)	1	6	6	27	33	3/4	11	14	3
6	3/10	3/21	11	3/16(7) 3/17(12) 3/18(1) 3/19(8) 3/20(11)	5	39	8—	?	?	?	?	6	?
7	4/29	5/16	17	5/7(16) 5/9(3) 5/12(7) 5/13(5) 5/14(7)	5	38	8—	0	38	5/4	3	9	6
8	7/25	8/11	17	7/30(7) 7/31(10) 8/1(6) 8/2(7) 8/3(3) 8/4(1) 8/5(1)	7	35	5	0	35	7/26	4	5	1
9	8/23	9/6	14	8/29(24) 8/30(8) 8/31(5) 9/1(1) 9/2(5) 9/3(1) 9/5(6)	7	50	7+	0	50	8/28	1	6	5
10	8/25	9/5	11	8/31(2) 9/1(2) 9/2(5) 9/3(1)	4	10	2+	6	16	8/29	2	6	4
11	9/14	10/3	20	9/19(11) 9/22(5) 9/23(4) 9/24(3) 9/25(2) 9/26(2) 9/27(2) 9/29(4)	8	31	4—	?	?	?	?	5	?
12	10/2	10/16	14	10/9(7) 10/10(1)	2	8	4	10	18	10/8	1	7	6
13	10/5	10/18	13	10/10(4) 10/11(9) 10/12(3) 10/13(2) 10/14(3) 10/16(4) 10/17(3)	7	28	4	?	?	10/7	3	5	2
14	11/8	11/25	17	11/16(7) 11/18(1) 11/19(2) 11/21(1) 11/22(2) 11/23(5) 11/24(10)	7	28	4	2	30	11/14	2	8	6
15	11/6	11/22	16	11/15(2) 11/16(12) 11/18(4) 11/19(3) 11/20(6) 11/21(4) 11/22(3)	7	34	5—	3	37	11/14	1	9	8
16	11/10	11/20	10	11/16(5) 11/17(9) 11/18(2)	3	16	5+	0	16	11/14	2	6	4
				TOTALS	91	438			395				72
				AVERAGES	5.6	29+			30+				4.5

TABLE II

Number	Date found	Date of death	Days alive	Dates and number of eggs laid in each batch. (Number of eggs given in parenthesis)	Total number of batches	Total number of eggs laid	Average number of eggs per batch	Eggs contained in body after death	Potential total of eggs
1	2/21	3/10	18	3/1(6) 3/2(9) 3/3(4) 3/4(2) 3/5(1) 3/6(6) 3/8(2) 3/9(7)	8	37	5—	1	38
2	2/25	3/15	18	3/4(2) 3/5(2) 3/6(2) 3/7(3) 3/8(3) 3/10(1) 3/11(3) 3/12(7) 3/13(5) 3/15(2)	10	30	3	26	56
3	3/21	4/6	17	3/26(4) 3/30(8) 4/1(3) 4/2(3) 4/3(8) 4/4(9)	6	35	6—	?	?
4	3/21	4/6	17	3/25(16) 3/26(8) 3/27(2) 3/28(3) 3/29(2) 3/31(2) 4/1(3) 4/2(8) 4/3(1)	9	45	5	0	45
5	9/24	10/3	10	9/26(18) 9/27(14) 9/28(3) 9/29(2) 9/30(6)	5	43	9—	0	43
6	9/15	9/26	11	9/16(1) 9/17(7) 9/18(1) 9/19(5) 9/20(11) 9/21(2)	6	27	4+	?	?
7	9/24	10/11	18	9/26(14) 9/27(15) 9/28(1) 9/29(5) 9/30(10) 10/1(5) 10/2(6) 10/3(5) 10/4(4) 10/5(3)	10	68	7—	0	68
8	9/25	10/4	10	9/26(5) 9/27(6) 9/28(3) 10/1(1) 10/2(13)	5	28	6—	0	28
9	11/25	12/11	16	12/8,9,10,11,12(16) 12/11(3)	6	19	3+	14	33
10	12/24	1/8	15	12/4(7) 12/28(6) 12/31(2) 1/3(4) 1/6(1)	5	20	4	0	20
				TOTALS	70	352			331
				AVERAGES	7	35+			41+

The time between copulation and oviposition is shorter and less likely to vary than that between emergence and copulation. As a rule it is one or two days, though sometimes extending to 4 or 5, and in one instance reaching 13 days. After the first oviposition, egg batches continue to be laid from day to day for about 7 days. As the fifth column of Table I shows, one day can be said to be almost invariably the time elapsing between batches, although it sometimes reaches 2, 3, or 4 days. Only in one instance (Table II, horizontal column No. 10), and this in the case of a field-collected female, did this interval extend beyond the usual maximum of 4 to 14 days.

By the time oviposition ceases, usually all of the fully formed eggs within a female are laid, but it often happens that dead females contain 2 or 3 eggs, some a greater number, and this justifies the question of whether a second period of oviposition, possibly stimulated by a second mating, might not be an occasional, if not usual occurrence under field conditions. Positive evidence in this direction is the fact perhaps, that sometimes in the laboratory, and probably also in the field, females live several days after they cease to lay eggs. Van Zwaluwenburg, for instance, found that out of 77 females 34 died on the same date of oviposition but that 43 lived from one to ten days more, an average of 2.7 days after the last oviposition (unpublished records).

Movements and Distribution of Grubs:

No periodic mass migration of grubs, such as are induced by the more distinct weather variations in Connecticut, can be detected here. Observations in the field and the laboratory, using large soil containers and approximating field conditions as nearly as possible, indicate that in Hawaii the migrations of Anomala larvae are neither rapid nor extensive, and that, other conditions being satisfactory, the presence or absence of food are the main factors in determining their extent and direction.

If a field harbors grubs at all in quantity, its soil is invariably of the right temperature and sufficiently rich in organic matter to provide what seems to be an entirely satisfactory medium for the development of the entire first instar of Anomala. In this stage, therefore, grubs move but little and what has been said about the distribution of the eggs applies equally well to the distribution of the first instar larvae. However, it is only when the surrounding soil is particularly suitable as to moisture and food conditions, particularly when mud press has been applied, that grubs remain feeding and thriving in the same place for the duration of the complete larval life. More usually they evidently migrate until they come into contact with partly dry and rotted bits of cane, or with the living plant itself, under proper moisture conditions. Although this search for the right environment need seldom carry a grub far, it is generally sufficient to segregrate the second and third instar grubs from the eggs and first instars. As a rule, therefore, eggs and first instars are found together, nearer the surface and in greater concentration than second and third instars which are more evenly distributed throughout the soil.

Not very different from the above is the history of the grubs in those cases where a large batch hatches in accumulations of mud press or under a mat of trash, as has already been explained. The grubs may remain close to the surface for the

full length of the larval stage, if moisture conditions remain satisfactory, but usually even thick trash mats and large accumulations of mud press undergo a rather rapid process of thinning and drying out which in 2 or 3 weeks forces the grubs to seek a lower soil level. A varying proportion of the grubs then dies, perhaps often the greater proportion; but those that remain dig deeper into the soil and continue their life-cycle therein.

Pupae are very rarely found in the loose soil near the surface of the ground, where grubs are sometimes plentiful. They are more likely to be at somewhat lower levels, where the packed condition of the soil facilitates the formation of pupal cells; but this need not be more than a few inches deep, and, as a whole, it may be said that the distribution of pupae on a vertical, as well of course as on a horizontal plane, is the same as that of grubs of the second and third instars.

The horizontal distribution of grub population is invariably irregular. Even in the most heavily infested fields, grubs are usually found concentrated into variously sized "patches" of greater density than the areas separating them; and these patches may range widely as to size, shape, and density of the grub population. Some of these "patches" may consist of only one or two isolated stools very heavily infested; others may be larger areas, sometimes gradually merging into each other, or just as often, sharply delimited.

The causes of this peculiar distribution are probably not always the same. Certain well established peculiarities of the behavior of Anomala seem to account quite well for most cases; the nature of these probable factors permits the supposition that sometimes they act singly and sometimes in different combinations with one another. On the other hand, recent work by H. A. Wadsworth of the University of Hawaii and R. H. Van Zwaluwenburg of our staff, indicates that differences in the physical characteristics of the soil, as these affect its moisture-holding capacities, and to variations of which the Anomala egg and early stages are exceedingly sensitive, might provide sufficient explanation of the phenomenon even without taking into consideration other more obvious factors.

The tendency of Anomala females to deposit most of their eggs near the point of emergence from the soil is probably the most important of these other factors. Another one would be the exclusive dependence of Anomala larvae on some product of the cane plant for food in cases where the soil itself, for one reason or another, is not a satisfactory growth medium.

Observations in the laboratory, using large soil containers and approximating field conditions as nearly as practicable, indicate that the migrations of Anomala are neither rapid nor extensive and that other conditions being satisfactory, the presence or absence of food is the main factor in determining their extent and direction.

Though very simple, it may be worth while to detail here the experiments from which these observations were made.

For the first experiment two boxes, numbered one and two for the sake of convenience, with inside dimensions of 14 by 16 by 24 inches, were each filled with two different types of soil, in such a manner that the right half of each box contained soil with a minimum of visible organic contents from a field where Anomala were not present, while the left half contained soil very rich in trash and taken from a

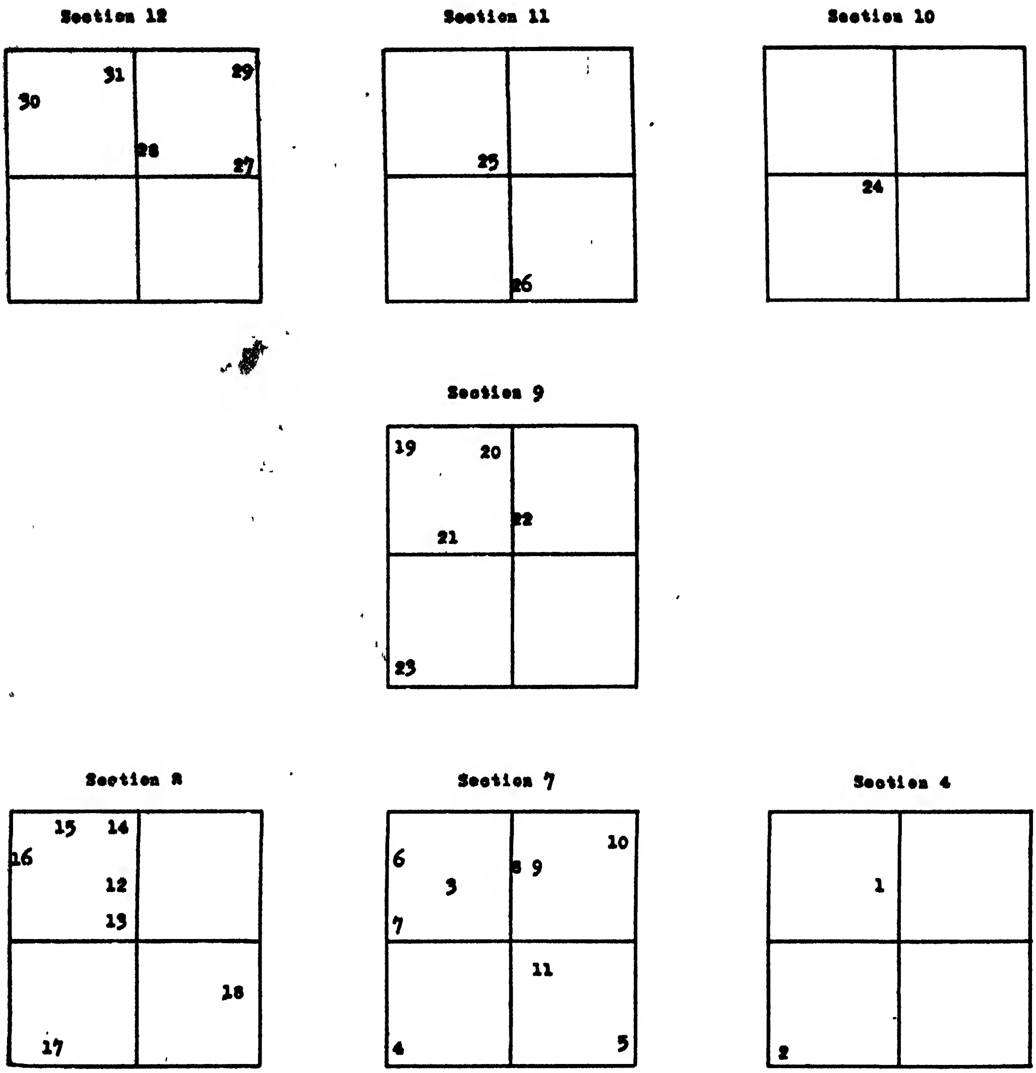


Fig. 1. FIRST MIGRATION EXPERIMENT, BOX NO. 1 (Vertical Section). Sections 12 to 7 comprised the trashy end of the box. Section 4 held the only 2 grubs which had moved beyond the trashy end. Intermediate sections are not shown.

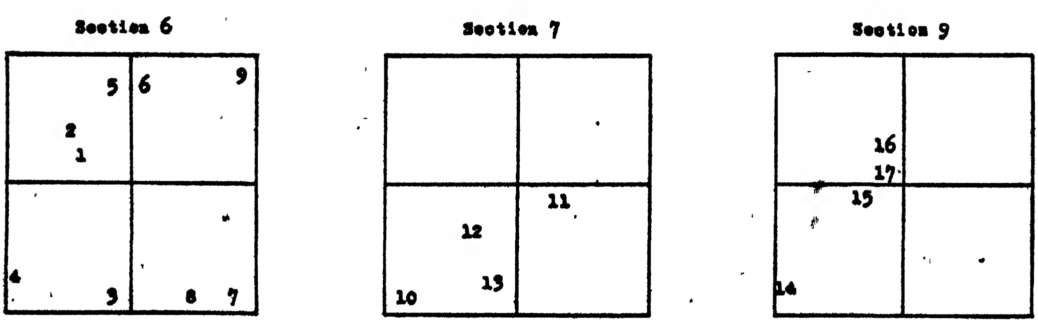


Fig. 2. FIRST MIGRATION EXPERIMENT, BOX NO. 2 (Vertical Section). All the sections shown here were in the trashy soil end of the box. Both trashy and non-trashy sections which showed no grubs are omitted.

thickly infested field. After watering daily and allowing the soil to settle for a week, it was allowed to dry down to an estimated field condition. Thirty-five freshly dug and quite healthy third instar grubs were then placed in each box; those in box number one were placed in a shallow groove along the surface of the trashy soil, while those in box number two were similarly placed in the trashless soil. Both boxes were then allowed to remain undisturbed for 15 days, after which one end and both sides of each box were removed, the boxes being so made that this could be done easily, and the remaining blocks of soil were carefully scraped off in thin cross-sections, record being made of the position of each grub.

The results obtained from this experiment are given in the following figures. Each square represents a two-inch section of soil, and each number corresponds to a grub and is placed in the proper relative position. There were 12 two-inch sections in each box, numbered consecutively from the poor to the rich soil end, but here are shown only those sections in which grubs were found; and record is made only of grubs, or of freshly emerged beetles which could be judged with reasonable certainty not to have moved from the place where they had pupated.

It will be seen that in box No. 1 (Fig. 1) where the larvae were placed in the rich soil, 31 out of 35 survived and all but two remained in trashy soil, the majority remaining in the upper half and evidently having moved but little during the time they remained in the box.

Fig. 2 shows that in the box where the grubs were originally placed on the poor soil, only 17 had survived and all had migrated to the trash. It is curious to note that 9 larvae, more than half of the total surviving, are found in section No. 6, indicating that for most grubs migration is over when food is found. This fact is also indicated by a comparison of the vertical distribution of the larvae in both boxes, which shows that in box No. 1, 21 out of the 31 surviving grubs remained in the upper half of the rich soil, while in box No. 2, 7 larvae were found in the upper and 10 in the lower half, showing a more even distribution, and therefore indicating more movement in poor than in trashy soil.

A second experiment on the migration of Anomala larvae corroborated the results of the one just detailed and gave some additional data on the distance that grubs may cover in their search for food. Using the same boxes and the same two types of soil, box No. 1 (Fig. 3) was filled entirely with poor soil from a non-infested field, except for a portion in the upper right hand corner, 8 inches deep, 8 inches long, and as wide as the box, which contained the soil mixed with trash. Box No. 2 (Fig. 4) was similarly filled, but the trashy soil was placed in the lower right hand corner. After a week of daily watering and another week of settling and drying to an approximate field condition, 35 grubs were introduced into each box, being placed in each case in a shallow groove in the corner diagonally opposite to the trashy soil. In this manner the grubs of box No. 1 had to move approximately 18 inches along an upward diagonal to reach the nearest trash, and those in box No. 2 had the same distance to move along a downward diagonal.

Thirty-two days after introducing the grubs, the sides and one end of each box were removed, and the soil carefully examined in the manner of the first experiment. The following diagrams, in which the cross-hatching indicates the presence of trash, show the results obtained.

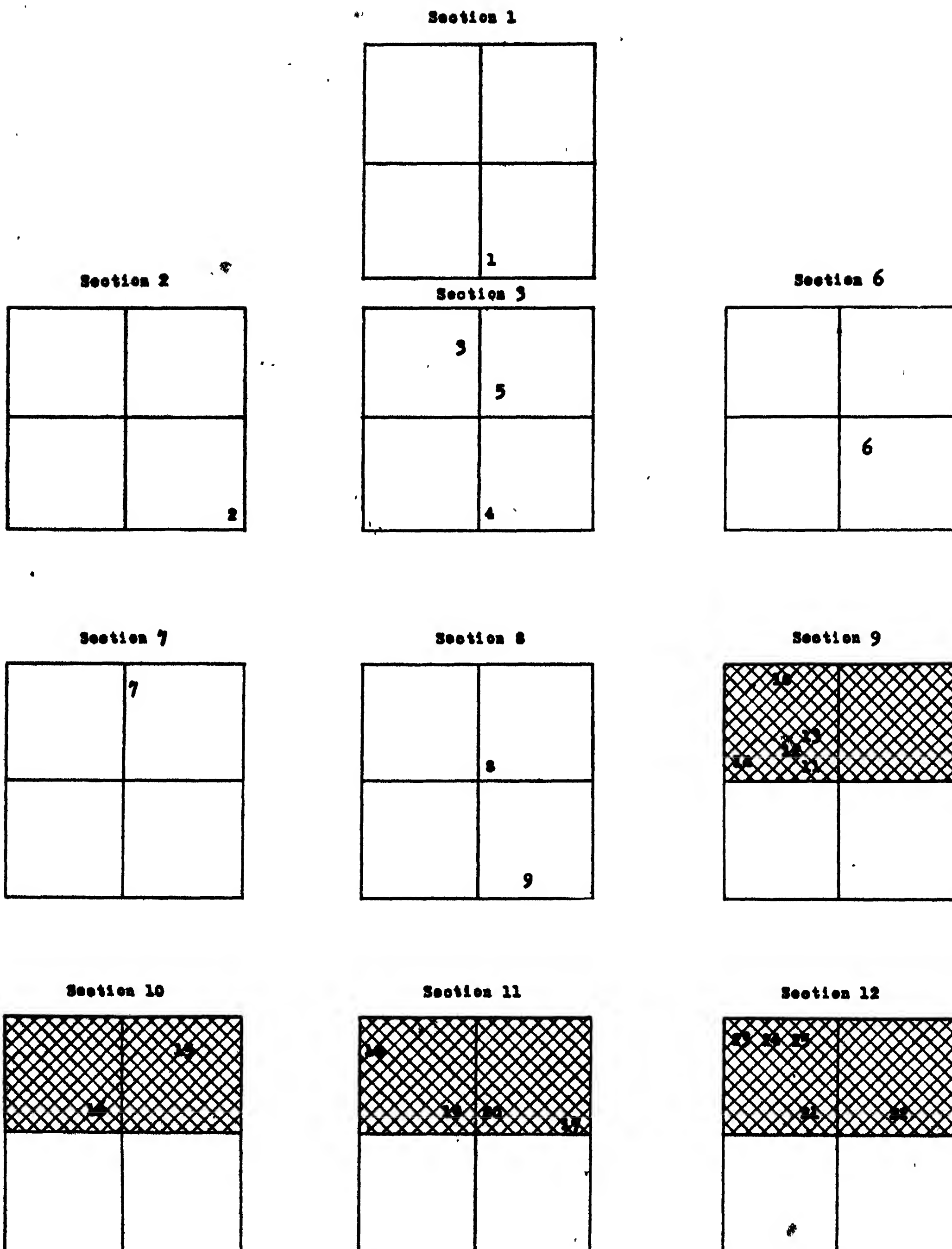


Fig. 3. SECOND MIGRATION EXPERIMENT, BOX NO. 1.

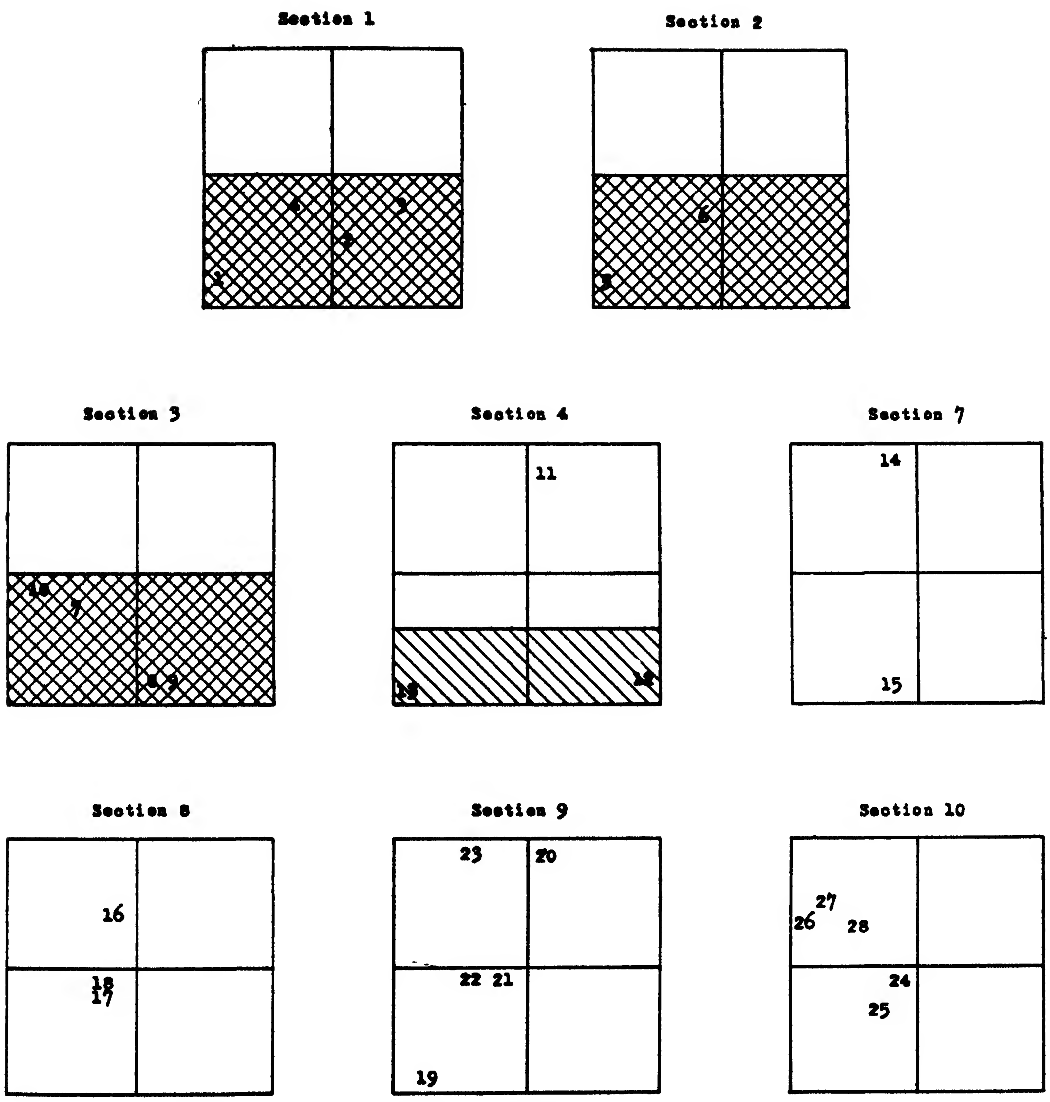


Fig. 4. SECOND MIGRATION EXPERIMENT, BOX NO. 2.

These results are not significantly different from those of the first experiment. Sixteen out of 25 grubs were found in the trashy soil in box No. 1, and 12 out of 28 in box No. 2. There is seemingly no tendency to prefer either a downward or upward course, and, as before, with other conditions satisfactory, food seems to be the main factor in determining the distribution of the larvae, although their migration is evidently very slow and their eventual contact with food seems to be a matter of chance rather than the result of any definitely oriented movement.

Food Habits of the Grub:

Friend states that in Connecticut young larvae feed on both grass roots and dead organic matter. As in the cane fields of the Oahu Sugar Company, Ltd., grass is usually quite scarce, it is probable that the first instar of Anomala lives and thrives almost entirely on the bacterial or organic content of soil which is continuously being passed through the alimentary canal. The second and third instars also ingest quantities of soil in the same manner, and may in many cases attain full development without consuming any other food. This has happened with laboratory-reared specimens. As a rule, however, the food of second and third instars in the field consists largely of different parts of the sugar cane plant, either in the living condition or in various stages of decomposition.

The common notion that the actual roots of the cane plant constitute the main article of fare is apparently erroneous. As a matter of fact all observations, both in the field and in the laboratory, indicate that grubs exercise but little choice in the matter of food, eating indiscriminately the nearest available cane plant material and moving on aimlessly in further search when this is consumed. This fact explains why an evidently heavy infestation of grubs is not accompanied always by a correspondingly great amount of damage to the cane. Other factors may account for this in some cases of course, but it is quite probable that often in fields where buried cane trash is abundant a large portion of the grubs to be found in the field are harmless, as far as the living cane is concerned.

The softer portions of the available food material seem to be more readily attacked, as might be expected. The pith of dry or semi-dry stalks is thus very often eaten, the grub making its way into the cane from one end, while the cortex remains unharmed. In the same way, eyes and young shoots are often partly or wholly devoured while the rhizome remains intact; but the opposite condition is also not rare, stools sometimes being found in which only the old, soft portions of the rhizome have been damaged, while the harder portion, supporting the eyes and buds, remains intact. In the case of seed pieces a very definite concentration of the area of damage has sometimes been observed, the eyes and the zone of adventitious roots being completely girdled out of otherwise practically unharmed cane.

Individual grubs in the laboratory varied considerably in their feeding habits. All of them would eat regularly of soil or trash during the first and second instar, but it was not unusual to find some of them that almost or possibly quite completely stopped eating sometime after entering the third instar. It was very evident that those that ate the most were the ones which could be expected to pupate relatively early; while a large proportion of the others would simply live on inactively and

indefinitely until attacked by some fungus or bacteria. One of these grubs survived for 318 days without consuming during its whole life a volume of food much larger than its own body at the point of greatest development.

It is interesting to note that these differences of behavior often occurred in the laboratory between grubs from the same batch of eggs, reared together in the same container. The cause or causes of these differences of behavior have not been ascertained.

Broods:

Entomologists who worked with Anomala before the introduction of Scolia believed that the pest produced two broods, possibly three, a year; but they were uncertain whether or not that was the case, and it seems improbable to us in the light of data gathered under less pressing demands for measures of immediate relief.

As far as it has been possible to determine the point, a number of generations are produced annually in the field. Overlapping is very great during the warm middle months, and, at least seemingly, lessens quite perceptibly after September. If overlapping actually diminishes it may be attributed to a general lengthening of the third instars of the last summer generation of grubs, most of which seem to remain in the soil longer than preceding generations, giving rise to a slowly trickling stream of emergence and oviposition which does not regain full vigor until the return of favorable conditions. However, it may quite well be that no such diminution of overlapping actually takes place, and that it only appears to occur as a result of the comparatively greater ease with which third instars are found because of their larger size and more general distribution through the soil, when these as well as all other stages of Anomala become relatively scarce in the fields. This condition, which invariably develops during the last months of the year, is due, perhaps, to more than a single factor, but is certainly in a large measure due to the efficient work of the introduced parasite, *Scolia manilae.*

Determination of the actual number of generations produced in the field is hardly possible because of the large degree of overlapping which is found whenever Anomala is abundant enough to make any sort of grub counts practicable. Judging from the results obtained in laboratory breeding work, under conditions probably far from ideal, as many as four generations might develop each year. This would allow around 90 days for the development of each generation; and the assumption that such a figure is nearly correct for at least the warm-weather generations offers an explanation of the very sudden rise—within 2 or 3 months—of Anomala population which is observed at times in fields where grubs left over the winter were so scarce as to be very difficult to find. Nevertheless, it is not to be doubted that in respect to larval life-lengths Anomala reflects in the field the almost limitless variety of environment which any field can provide. The wide overlapping of generations can hardly be due to any other factor.

Taking all that we know into consideration, it is almost certain that there is not even one brood of definite seasonal emergence. Abundance of beetles at certain times, which might be taken as an index of the time of emergence, is probably not due to Anomala's biologic habit, but to the seasonal concurrence of a number of

ecologic factors which cause very strikingly contrasted periods of alternate abundance and scarcity of the pest. If it did depend only on a biologic habit of the insect we could expect to find it occurring simultaneously over the whole infested area regardless of the age of the crop cover; but actually the time of greatest abundance varies from field to field, and, as a rule, coincides with cane not more than a few months old. Apart from that, in some fields it continues throughout spring and into late summer; much longer than we can expect a brood to last, regardless of overlapping, in case of an insect whose adult stage is only from 2 to 4 weeks.

It is easy to see why the point of maximum accumulation should be generally reached, as it is, late in spring. On the other hand, occasional wide divergence of individual fields from the general rule, observed more than once, does not become unexplainable, as it would if beetle abundance were due to seasonal brood emergence.

The Behavior of Adults in the Field:

When beetles are abundant above ground males are almost invariably far more numerous than females and can be found resting on weeds, trash, or cane leaves at any hour of the day. Although their antennae are usually outstretched and in slow movement, as if in constant expectation or actual reception of sensory stimuli of some sort, they are generally rather inactive and only a few can be seen commonly on the wing at one time. There are, nevertheless, periods of distinctly increased activity when all or most of the beetles rise in flight simultaneously. At such times they seem to rise in response to a stimulus which is, or coincides with, a sudden drop of the atmospheric temperature, either as when the sun is obscured by passing clouds in which case activity may last only a few minutes, or as when the sun is hidden in consequence of its downward path below the horizon, then activity suddenly begins and lasts with varying but gradually diminishing intensity until darkness sets in.

The object of the beetles' flight during crepuscular periods of activity seems to be to migrate from the exposed stations on which they can be found during the day to more protected locations under trash and surface soil, where most of them spend the night; and it is probably in search of the same protection that they fly when rain or cold is presaged by passing clouds. This object is less evident, however, during the day than in the evening, and the fact that often there is no apparent diminution of the number of beetles on exposed places during heavy showers points to the possible existence of a different cause for diurnal as compared to crepuscular activity.

The movement from soil and trash to the more exposed locations is not accomplished in concert. It gives rise, rather, to a trickling stream of individual flights which begins with the first warming of the air in the morning and continues through the day; its volume seems to vary from hour to hour and day to day, and is apparently greater in warm, sunny weather than when it is cold or rainy.

The dull thud, with which Anomala males often collide against leaves of cane plants or against the backs of their human visitors, suggests a greater potential ability for prolonged flight than the writer has ever seen actually exercised. The males never fly directly to a point, and seldom, if ever, rise higher than a man's head. Their flight is always of short duration, more or less spiral, and always seemingly erratic, succeeding more often than not in bringing the insect back to within a few

feet of its point of departure. There have been one or two occasions, however, when the flights of several males were observed by the writer to be drawn to a common point of convergence by the presence of a female, and in these cases, although each individual wasted much effort in useless spiraling, most of them finally landed within a foot or two of the female.

Females, which the writer has observed on the wing, behaved in a manner apparently no different from that of the more numerous males, providing no foundation for the belief that females may arise in mass to migrate directly from one field to another. Quite commonly during the earlier years of Anomala's presence, at the present time less frequently, unusual numbers of females have been found congregated on flowers, particularly on those of *Leucaena glauca,* but this has never been known to happen unless flowers were growing within or immediately adjacent to infested fields. The movement to these flowers has been observed by the writer to take place not by migration in mass but through the flight of isolated individuals. The gradual accumulation of females on flowers during the day, and their more nearly simultaneous flight back to the soil at dusk, are, as a matter of fact, activities exactly parallel in appearance to those of the males in moving to and from the cane leaves on which they are usually found during the day.

The fact that females are not at present conspicuous as seems to have been the case in former years, is probably due to the more occasional concurrence of attractive flowers and females in closely adjacent locations. It would seem that it is a regular and general habit of females—after laying most of their eggs as discussed earlier—to frequent flowers; but the distance which they can traverse to do so, or the distance from which they are able to perceive the flower, is rather limited. How limited this flight is can perhaps be judged from the fact that the writer has never found females farther than 30 feet from a focus of grub infestation.

It is a curious fact that in infested fields beetles are as unevenly distributed on the surface as grubs are underground. Large portions of a field will show only a few beetles, whereas certain scattered areas, during active periods, will be alive with their buzzing, as if beetles tended to retain the original concentration of their larvae rather than to disperse in every direction, as one would expect them to. In some cases this concentration takes place in response to the attraction of females; it is not unusual to find large numbers of males crawling over and around mating couples. In most cases it is perhaps due merely to a purely gregarious instinct, as it is not uncommon to find large clusters of males spending the night together in propitious locations under loose soil or trash, unaccompanied by females.

In frequenting flowers, in the case of *Leucaena glauca,* females do so to feed exclusively upon the pollen and pollen bearing elements of the flower. The petals of other flowers also seem to be relished, as in the case of hibiscus, petals of some varieties of which serve very well as a laboratory diet for the beetles. Whatever the variety of flower, it is probable that the scent rather than the sight of the flower guides Anomala to it. That being the case, the beetles' habit of frequenting flowers suggested experiments conducted in the field on the possibility of attracting them to baited traps; but the results, although not entirely negative, proved discouraging. Using traps of a pattern devised and previously employed by entomologists of the

U. S. Department of Agriculture in connection with similar research on the Japanese Beetle, our trials were made with six different volatile oils, applied in each case at the rate of one drop of oil to each portion of the following formula, secured from the Moorestown Experiment Station: 50 grams of bran, 26 cc. of cane molasses, 4 cc. of glycerine, 9 cc. of water, and 0.1 gram of benzoate of soda. Six traps, each with a different oil, were used simultaneously, all being placed within 100 feet of one another in a field chosen for the exceptional abundance of beetles above ground. Changing the site each time, the experiment was repeated two times within as many months in 1932—having been conducted once in 1931. As the results were entirely negative in all but one case, only that instance is recorded in the following table.

TABLE III

THE RELATIVE ATTRACTIVENESS OF SIX VOLATILE OILS FOR ANOMALA ADULTS

Traps Set Out April 9, 1932.

	Geranol	Anisic Aldehyde	Terpineol	Citronellol	Amyl Acetate	Ethyl Benzoate
April 14....	Anomala 1	Anomala 1	Anomala 1	Anomala 1		
	Anomala 0	Anomala 0	Anomala 0	Anomala 0		
	Scolia 6	Scolia 8		Scolia 2		
				Adoretus 1		
April 17....	Anomala 2	Scolia 3				
	Anomala 0					
	Scolia 5					
April 21....	Anomala 1	Scolia 1		Anomala 1		
	Anomala 0					
	Scolia 2					

As only female Anomalas were captured, and as these are almost at all times scarcer than males in the field and certainly were so in this particular instance, the results of this experiment definitely show a certain degree of attraction of at least four of these oils for the female beetle; the attractiveness of Geranol was somewhat greater, perhaps, and lasted somewhat longer than that of the others. However, the fact that all of the trapped females turned out to be entirely devoid of eggs, together with the fact that the oils seemed to have as much or more attraction for Scolia females than for Anomala, showed the uselessness of further experimentation with this method of control.

Entirely negative results were obtained with similar experiments when the same traps were baited with cane molasses, honey, or a mixture of both.

Life History in the Laboratory

The results of life history work done in the laboratory are given herewith. The scarcity of Anomala beetles and grubs in the field during a large part of the time the work was carried on, added to the natural difficulties of determining the life history of grubs under the best of laboratory or field conditions, explains their meagerness.

Lacking space and facilities for the purpose, no effort was made to keep constant temperature, or in any way to control the conditions under which Anomala

material was reared. It was merely kept under an open lean-to where temperature changes roughly corresponded to those of the open air. The records, therefore, can hardly be more than an indication of field possibilities; but, as such, they are in satisfactorily close agreement with results obtained by Mr. Van Zwaluwenburg in a more careful and detailed continuation of life history studies now being carried on.

Several methods of breeding Anomala under observation were tried. At first an effort to approximate field conditions was made by keeping grubs in boxes and other large soil containers; but it was soon found that the use of large containers, some of which were buried in the ground, only increased the necessary labor, without reducing the mortality of young grubs, which was the main difficulty faced in securing the desired data. The method finally adopted was the use of tin pill boxes 2½ inches in diameter and ¾ inch in height, not quite filled with soil and pieces of cane rhizome, and kept on a shelf at ordinary shade temperature. Unless extraordinarily large, each batch of Anomala eggs, averaging from one to ten, was hatched in a single pill box wherein the grubs were also allowed to remain together. Naturally, in this way each batch would soon be thinned out to one or two grubs per box, but this was found to be the eventual fate of every batch of grubs kept in the laboratory, regardless of the manner of keeping them. After only one or two grubs out of each batch were left they became, of course, much easier to observe and to keep supplied with food and moisture in small containers than it would have been in large ones.

The most striking fact brought out by this work was the great range in the duration of the various instars of the grub stage of Anomala. This becomes even more striking when it is considered that in several cases widely separated figures in the tables here given represent instars of grubs from the same batch of eggs, reared together within the narrow limits of ecological variation determined by the size of a pill box. One is led to suspect that the range of dispersion must be even greater under the uneven environmental conditions of a cane field.

It would have been interesting to ascertain the degree of correlation that exists between the lengths of the various instars of the same grub, but due to the heavy mortality in all stages of the reared material very little data could be secured bearing on this point. As it was, this correlation seemed entirely negative, as Table IV will show. Therein are given the only 3 complete beetle histories obtained.

TABLE IV

Beetle	Sex	Length of 1st instar	Length of 2nd instar	Length of 3rd instar	Pupal Stage
1	?	44 days	20 days	90 days	? days
2	?	15 days	24 days	105 days	? days
3	Female	29 days	26 days	68 days	7 days

Table V presents in condensed form the lengths of 67 first, 48 second, and 11 third instars.

TABLE V

	Minimum length	Maximum length	Average	Probable error
67 1st inst..................	11 days	54 days	24.2 days	.58
48 2nd inst..................	10 days	66 days	28.7 days	1.2
11 3rd inst..................	47 days	176 days	105.2 days	Very large

Table VI gives the total lengths of 37 larval stages, from hatching of the egg to pupation of the full-grown grub. Both this table and the preceding one, Table V, show wide dispersion, but as in Table VI, 20, or more than half of the 37 items, fall within the interval of 140 to 190 days, while the rest spread over a much larger range, the average figure of 172.3 days is probably fairly representative. It is to be noticed, however, that neither of these tables shows the entire possible range of the larval stage. It can be considered longer than here indicated because these tables are computed only from grubs which actually pupated; whereas, as already noted, a few larvae kept under observation in the laboratory showed an unusual protraction of the third instar that might eventually have terminated in the grub's pupation, but which for one or another extraneous reason was not brought to an end in that manner. One of these grubs, the longest lived, survived for 318 days—others approximately that long.

Due to the arrangement of the figures in progressive order as shown in Table VI, a glance shows that there is no correlation between length of larval life and time of egg hatching, but it must be noticed that all of these grubs were hatched during the third, fourth, fifth and sixth months of the year, between which months changes in temperature are very slight. Had it been possible to begin rearing a certain number of grubs each month of the year under conditions so controlled as to reflect the seasonal weather variations of the field, it is quite probable that a correlation between length of larval life and time of oviposition such as evidently occurs in the usual field environment of Anomala, would have appeared.

In Tables VII and VIII the items are too few to permit the use of the results as basis for any definite conclusion, being in close agreement with all other data thus far obtained by our department; they are, however, probably correctly indicative. As can be seen, the range in the duration of the pupal stage is rather small in the case of both sexes. On the other hand, this range is rather wide in the case of both male and female adults. As the results agree with later observations made by Mr. Van Zwaluwenburg, the slightly longer averages of the males over the females, for both pupal and adult stages, seem to be significant; and it is curious to note that this agreement exists in spite of the fact that his beetles were continuously fed on hibiscus flowers, of which they are very fond, whereas those of the writer were not fed at all.

TABLE VI

TOTAL LENGTH OF LARVAL LIFE OF ANOMALA FROM HATCHING OF THE EGG TO PUPATION OF GRUB

Item No.	Date Egg Hatched	Date of Pupation	Total days of Larval Life
1	4.20	7.10	82
2	3.27	7.19	115
3	6.17	10.8	114
4	3.26	7.19	116
5	3.16	7.13	120
6	3.17	7.16	122
7	12.31	4.15	134
8	4.20	9.14	148
9	4.17	9.14	151
10	5.29	10.28	153
11	10.41	3.7	155
12	4.11	9.5	158
13	4.11	9.5	158
14	5.22	10.27	159
15	4.24	9.29	159
16	5.24	10.30	160
17	3.22	8.29	161
18	4.22	9.30	162
19	5.24	11.1	162
20	3.18	8.26	162
21	3.18	8.28	164
22	3.20	9.5	170
23	4.12	10.4	176
24	9.13	3.7	177
25	3.20	9.15	179
26	3.30	9.28	183
27	4.20	10.20	184
28	4.20	10.27	191
29	6.25	1.11	201
30	4.20	11.16	211
31	6.20	1.21	216
32	6.81	1.22	229
33	5.27	1.11	230
34	5.28	1.30	248
35	5.22	1.21	245
36	4.20	1.1	257
37	4.21	1.11	266
		TOTAL	6378
		AVERAGE	172.3

TABLE VII

LENGTH OF PUPAL AND ADULT STAGES OF MALE ANOMALA BEETLES

Item No.	Date of Pupation	Date of Emergence	Date of Death	Days as Pupa	Days as Adult
1	August 18	August 26	September 8	8	13
2		December 1	December 27		26
3		April 7	April 19		12
4	May 20	May 31		11	
5	September 30	October 10		10	
6	September 4	September 14		10	
7	August 29	September 7		9	
8	January 26	February 10		15	
9	January 15	January 27	February 15	12	19
10	January 11	January 25	February 15	14	21
11		January 5	January 31		26
12		January 13	February 1		19
13		February 23	March 3		8
14		February 27	March 9		10
15		February 11	February 20		9
16		March 8	April 1		
17		March 13	April 2		
			AVERAGES	11.1	16.3

TABLE VIII

LENGTH OF PUPAL AND ADULT STAGES OF FEMALE ANOMALA BEETLES

Item No.	Date of Pupation	Date of Emergence	Date of Death	Days as Pupa	Days as Adult
1	November 15	November 28	December 7	13	10
2	March 22	April 2		11	
3		May 14	June 1		18
4	May 15	May 22		7	
5	May 15	May 23		8	
6	May 15	May 24		9	
7		May 21	June 1		11
8		May 22	June 15		24
9		April 13	May 14		31
10		July 20	August 1		12
11		March 10	March 21		11
12		February 17	March 4		15
13		January 29	February 17		19
14		March 1	March 16		15
15	April 16	April 29	May 16	13	18
16		July 25	August 11		17
17	August 14	August 23	September 6	9	14
18	August 16	August 25	September 5		11
19		October 2	October 16		14
20		October 1	October 13		12
21		October 5	October 18		13
22		November 8	November 25		17
23		September 14	October 3		19
24		November 6	November 22		16
25		January 14	January 30		16
26		November 10	November 20		10
			AVERAGES	10.0	15.5

TABLE IX

LENGTH OF THE PERIOD OF INCUBATION OF BATCHES OF ANOMALA EGGS LAID IN THE LABORATORY DURING THE VARIOUS MONTHS OF THE YEAR

Month	Number of Batches	Minimum Incubation	Maximum Incubation	Average Incubation	Mean Monthly Temperature
January	7	21 days	23 days	22.1 days	64.5° F.
February	3	18 days	19 days	18.3 days	65.9° F.
March	22	16 days	21 days	19.1 days	62.2° F.
April	17	16 days	22 days	18.1 days	65.2° F.
May	6	14 days	15 days	14.8 days	66.5° F.
June	5	14 days	15 days	14.4 days	67.2° F.
July	..	......	......	....	....
August	7	14 days	20 days	15.4 days	67.0° F.
September	9	12 days	16 days	16.3 days	66.0° F.
October	15	12 days	18 days	14.5 days	68.0° F.
November	..	......	......	....	....
December	4	18 days	22 days	21.0 days	64.9° F.

While not correlating perfectly, the monthly averages for the incubation period of Anomala eggs, as given in Table IX, reflect clearly the general tendency of the temperature curve for the year. By arranging the months of the year in two columns, as follows, in which the first column is in the order of the progressive decrease of the mean incubation period, and the second one in the order of the progressive decrease of the mean monthly temperature, this correlation can be seen at a glance.

Length of egg stage decreases in this order:	Mean monthly temperature decreases in this order:
June	October
October	June
May	August
August	May
September	September
April	February
February	April
March	December
December	January
January	March

Correlation is, of course, to be expected between variations in temperature and the length of the period of egg incubation; but a great deal of work now being carried on by Prof. H. A. Wadsworth and Mr. Van Zwaluwenburg under carefully controlled conditions is showing this correlation to be very delicate, thereby throwing light on its probably very great importance in the field.

In Table IX the figures refer to egg batches as a whole, rather than to individual eggs. It was never noticed in this work that individual eggs of the same batch, kept together in the same small container, differed by more than a few hours as to the length of the incubation period, and these small differences are overlooked. As at least two daily observations were made of the material, however, it is probable that the figures are accurate to within 12 hours.

Emergency Conservation Work
Associate Forester's Narrative Report
Island of Kauai—For Fifth ECW Period*

This report covers the work of our program of Men Working From Homes from April 1 to September 30, 1935 and the camp program from July 22 to September 30, 1935. Construction of the camp began on May 17, and it was completed on August 16, 1935. Men for the camp were enrolled on July 8, 1935, and after a two weeks' conditioning period, work started on approved field projects on July 22. Men working from homes were paid at the rate of $2.00 per day, 5 days per week, the camp enrollees being paid $30.00 per month plus subsistence, shelter, clothing and medical care.

Men Working From Homes—the maximum enrollment allowed was 54 men and 5 field foremen. Six men were employed in nurseries and 48 men on field projects. The men were divided into five groups in accordance with the various districts on the Island. At the start of the camp program, the group including the foreman working in the district in which the camp is located was transferred to camp. Another foreman was transferred to camp and promoted to Project Superintendent, leaving 45 men and 3 foremen.

The authorized strength of the camp is 100 enrolled men with a Supervisory personnel consisting of a Director, Project Superintendent, Quartermaster and Recreational Officer, Clerk and 5 Foremen.

During the period a total of 9,120 man-days was expended on all projects. Due to the fact that the camp enrollees did not start work on projects until July 22, a number of the contemplated projects remained incomplete at the termination of this period. These will be completed along with the program prepared for the ensuing period commencing October 1, 1935.

Work Projects

The work program for this island includes the following approved projects as listed on ECW Form-7—N. P. & M.:

1. Fences, Construction and Maintenance
2. Field Planting and Maintenance
3. Foot Trails, Construction and Maintenance
4. Horse Trails, Construction and Maintenance
5. Truck Trails, Construction and Maintenance
6. Minor Roads, Maintenance
7. Erosion Control, Planting and Maintenance
8. Dwellings, Improvements
9. Water System
10. Bridges
11. Structures
12. Razing Undesirable Structures
13. Eradication of Plant Pests
14. Seed Collection
15. Nurseries

* We are indebted to E. E. Tillett, Field Supervisor, Emergency Conservation Work for Hawaii, for the privilege of printing this report by Albert W. Duvel.

WORK ACCOMPLISHED

BY L. V. ALEXANDER, PROJECT SUPERINTENDENT

A. Camp Projects

During the Fifth Period from July 8 to September 30, 1935 inclusive, a total of 360 man-days was expended on conditioning period and 3,439 on work projects. The cost of materials used on projects totalled $336.57. Total Supervisory costs were $1,634.50.

During the conditioning period, 360 man-days were expended on various forms of activity and work to get the enrollees in condition. One-tenth of a mile of truck trail was built for the camp. Four thousand eight hundred forty square yards of fine grading and road bank sloping were taken care of. One thousand seventeen trees and plants were brought from the Forest Reserve and placed in and around the camp. One dump was obliterated. One acre of ground was sodded with grass and one acre of ground thoroughly prepared preliminary to planting. About 210 cubic yards of excavating were done and the dirt used to fill in other places. One hundred cubic yards of stone were broken for use around camp. One thousand lineal feet of rock lining were constructed to form walks around the barracks. Twelve yards of sand were hauled for use in the camp. Nine hundred two feet of ditching were constructed within the camp and fifty cords of firewood were cut for the camp wood supply.

Field Projects

1. Fences:

ECW Form-7 No. 131. This project consisted of the repairing and maintenance of 168.4 rods of fence along the Puu Ka Pele Forest Reserve boundary. A total of 44 man-days was expended on this project. Material costs: $4.25. Supervisory costs: $21.60.

2. Field Planting and Maintenance:

ECW Form-7 No. 501. Field planting and maintenance work was carried on in the Puu Ka Pele Forest Reserve. A total of 49 acres was planted. Nine thousand one hundred forty-three trees were planted, spaced at a distance of 15 x 15 feet. Under maintenance, 242 acres were cared for. Fifty-seven thousand two hundred ten trees were hoed free from grass, weeds, and brush, and 5,269 trees were replanted. The three varieties used were Grevillea robusta, Acacia koa, and Eucalyptus rudis, these having been found to be the varieties best suited for the conditions prevailing in this section. Man-days expended for the new planting and maintenance were 269. Material costs: none. Supervisory costs: $121.27.

3. Foot Trails, Construction:

ECW Form-7 No. 206. This project consisted of the construction of seven-tenths of a mile of foot trail along a very steep and rugged section of the Puu Ka Pele Forest Reserve boundary to facilitate fence patrol and tree planting. Forty

man-days were expended on this work. Material costs: none. Supervisory costs: $17.95.

4. Horse Trails, Construction and Maintenance:

ECW Form-7 No. 207. This project consisted of the construction and maintenance of horse trails within the Puu Ka Pele and Na Pali Kona Forest Reserves. Nine miles of horse trails were built with an expenditure of 650 man-days. Material costs: none. Supervisory costs: $270.12.

Seven miles of horse trails were partially completed. Three hundred eighty-two man-days were used on this work. Material costs: none. Supervisory costs: $168.70.

Horse trails, maintenance—29½ miles were placed in serviceable condition. A large number of steep grades were reduced to conform with Park Department regulations. A total of 1,357 man-days was expended on this work. Material costs: none. Supervisory costs: $745.11.

5. Truck Trails, Maintenance:

ECW Form-7 No. 202. This project consisted of truck trail maintenance in the Na Pali Kona Forest Reserve, Kokee. A total of nine-tenths of a mile of truck trail was placed in serviceable condition. One hundred nine man-days were expended on this work. Material costs: none. Supervisory costs: $44.23.

6. Minor Roads, Maintenance:

ECW Form-7 No. 203. This project consisted of the maintenance of 3.2 miles of minor roads within the Na Pali Kona Forest Reserve. This work was especially needed to give access to the various trails and work projects within the region. Two hundred thirty-eight man-days were expended on this project. Material costs: none. Supervisory costs: $112.40.

7. Dwellings, Improvements:

ECW Form-7 No. 110. Maintenance of Ranger Station dwelling at Kanalohuluhulu. This work consisted of covering the outside walls with heavy building paper and shingles, staining shingles and painting the trimming. A total of sixty man-days was expended on this project. Material costs: $122.80. Supervisory costs: $26.40.

8. Water System:

ECW Form-7 No. 143. This project consisted of a pipe line and water system at the old Na Pali Kona Ranger Station, Kokee. The project was only partly completed at the end of this period. A dam has been constructed on the main Kokee Stream to furnish a water supply. Owing to conditions existing at the dam site, rather more time and material were required than originally estimated. Forty-five man-days were expended on this project. Material costs: $209.52. Supervisory costs: $19.80.

9. Eradication of Plant Pests:

ECW Form-7 No. 1004. This project consisted of the eradication of blackberry in the Kokee Region of the Na Pali Kona Forest Reserve. This plant with others of the family group has spread, covering a large area and forming an impenetrable mass. It has been necessary to keep after the new growth continually and to remove every root that can be found within the vicinity. A total of nine acres has been cleared off, with an expenditure of one hundred ninety-seven man-days. Material costs: none. Supervisory costs: $86.92.

B. Men Working from Homes

Under this program a total of 5,321 man-days was expended during the period with supervisory cost of $2,776.03. The cost of materials used on the various projects came to $1,051.56.

Field Projects

1. Fences, Construction and Maintenance:

ECW Form-7 No. 131. During the period 335.1 rods of fence were constructed along the Lihue-Koloa Forest Reserve boundary. This fence has been a great assistance in keeping trespassers and live stock from the reserve. Eighty-eight man-days were expended on this project. Material costs: $132.88. Supervisory costs: $49.50.

Under maintenance, 715.1 rods of fence were cared for and placed in serviceable condition. One hundred rods were in the Lihue-Koloa Forest Reserve and 615.1 rods in the Moloaa Forest Reserve. Ninety-six man-days were expended on this project. Material costs: none. Supervisory costs: $23.50.

2. Field Planting and Maintenance:

ECW Form-7 No. 501. During the six-month period a total of 150.1 acres of new planting was completed. Eleven hundred man-days were expended on this work with $560.00 for supervisory costs and no expense for material.

The plantings were divided as follows: Lihue-Koloa Forest Reserve 74.8 acres, Kealia Forest Reserve 14.8 acres, Halelea Forest Reserve 25 acres, and Nonou Forest Reserve 35.5 acres.

Under maintenance a total of 78,688 trees was planted, the main varieties being Acacia, Albizzia, Eucalyptus, and Grevillea robusta. Smaller numbers of several other kinds of trees were planted to test their usefulness under the conditions prevailing at various localities in the forest reserves. The trees were furnished by the Lihue and Kalaheo Nurseries and carried to the planting areas by CCC trucks.

Under maintenance a total of 283.7 acres was cared for with the expenditure of 884 man-days and material expenditures of $5.70. Supervisory costs were $353.33. A total of 117,734 trees was cared for. Due to the unusually dry condition which prevailed generally, the losses were much heavier than generally anticipated. The areas maintained were as follows: Lihue-Koloa Forest Reserve 36.9 acres, Kealia Forest Reserve 98.8 acres, and Nonou Forest Reserve 148 acres.

3. Foot Trails, Construction and Maintenance:

ECW Form-7 No. 206. In the Moloaa and Nonou Forest Reserves 2.4 miles of foot trails were constructed to give access to areas otherwise inaccessible for planting. Man-days expended were 148. Material costs: none. Supervisory costs: $58.50.

Under maintenance a total of 5.4 miles of foot trails was maintained and kept in serviceable condition within the Moloaa, Nonou, Kealia and Lihue-Koloa Forest Reserves. One hundred fifty-seven man-days were expended on this project. Material costs: none. Supervisory costs: $72.00.

4. Horse Trails, Construction and Maintenance:

ECW Form-7 No. 207. Two and five-tenths miles of horse trails were constructed with a total use of 235 man-days. Material costs: none. Supervisory costs: $128.00. These trails were needed to give access to planting areas and to provide a way into the reserves so that the rangers could efficiently patrol the areas. One mile was constructed within the Kealia Forest Reserve and 1.5 miles within the Na Pali Kona Forest Reserve.

Under maintenance a total of 8.8 miles of horse trails was cared for and kept in serviceable condition within the various forest reserves. A total of 1019 man-days was expended on this project. Material costs: $147.54. Supervisory costs: $650.50.

Some sections required the use of a considerable amount of powder work, especially the Haena-Kalalau Trail along the Na Pali Kona Coast where it was necessary to remove a number of rock ledges that obstructed the trail.

Trails maintained within the various forest reserves are as follows: Na Pali Kona Reserve, Haena 4.4 miles, Na Pali Kona Reserve, Kokee 2.2 miles, and Kealia Reserve, Anahola 2.2 miles.

5. Truck Trails, Construction and Maintenance:

ECW Form-7 No. 202. Five-tenths of a mile of truck trail was constructed within the Lihue-Koloa Forest Reserve to give access to a large area in need of planting. One hundred thirty-nine man-days were expended on this project. Material costs: none. Supervisory costs: $64.00.

Under maintenance a total of 5.3 miles of truck trails was maintained and kept in serviceable condition within the Na Pali Kona, Kealia and Lihue-Koloa Forest Reserves. A total of 98 man-days was expended on this project. Material costs: none. Supervisory costs: $45.00.

6. Erosion Control, Planting and Maintenance:

ECW Form-7 No. 307. A total of 4840 square yards of gullies was sloped and planted within the Nonou Forest Reserve requiring an expenditure of 20 man-days. Twelve hundred trees were planted within this area. Material costs: none. Supervisory costs: $9.00.

Under maintenance a total of 33,880 square yards of gully plantings was maintained within the Nonou Forest Reserve. A total of 8195 trees was cleared of

weeds and maintained during the period. Material costs: none. Supervisory costs: $9.00.

7. Foot Bridges:

ECW Form-7 No. 101. One foot bridge was constructed within the Na Pali Kona Reserve over the Halemanu Stream. Material for construction of the bridge was obtained from the immediate vicinity of the stream. Material costs: none. Supervisory costs: $14.50.

8. Structures:

ECW Form-7 No. 120. One glass-roofed, seed-germinating house was constructed at the Kalaheo Nursery requiring an expenditure of 12 man-days. This will aid greatly in the production of plants and trees at the nursery. Material costs: $71.19. Supervisory costs: $10.00.

9. Razing Undesirable Structures:

ECW Form-7 No. 713. One undesirable structure within the Lihue-Koloa Forest Reserve at Wahiawa was razed, eliminating danger of tresspassers and possible fires. All usable material was taken to the Kalaheo Nursery and used in nursery repairs and improvements. Twenty man-days were expended on this project. Material costs: none. Supervisory costs: $9.00.

10. Seed Collection:

ECW Form-7 No. 505. Eighty-four pounds of seeds of various kinds were collected, aiding greatly in the production of trees at the nurseries at a minimum of cost. Sixty-three man-days were expended in seed collection with a supervisory cost of $27.00.

11. Nurseries:

ECW Form-7 No. 503. A total of 1213 man-days was expended on nursery work as follows: Kalaheo Nursery 540, and Lihue, Grove Farm Nursery 673.

Material cost for both nurseries $693.53. Supervisory costs: $498.33.

A report on the output of the two nurseries will be found elsewhere in this report. Both nurseries have been considerably enlarged to fill the needs of the planting requirements of the CCC.

Summary of Work Projects

The following summary includes all work accomplished on projects by the Camp enrollees and Men Working From Homes during the past six months.

1. Planting Forestation:

A total of 91,613 trees, covering 199.1 acres, was planted during the period on government lands within various forest reserves as follows:

Lihue-Koloa Forest Reserve

Acacia dealbata	55	
Acacia koa	222	
Albizzia moluccana	4,544	
Araucaria excelsa	830	
Eucalyptus citriodora	2,175	
Eucalyptus robusta	3,000	
Enterolobium cyclocarpum	1,826	
Grevillea robusta	16,674	
		29,326 trees

Kealia Forest Reserve

Acacia dealbata	80	
Casuarina glauca	2,430	
Eucalyptus citriodora	405	
Eucalyptus robusta	1,583	
Fraxinus americana	49	
Grevillea robusta	52	
Melaleuca amarillis	7	
Melaleuca leucadendron	220	
Tristania conferta	60	
Salix sp.	9	
Spondias lutea	300	
		5,195 trees

Halelea Forest Reserve

Acacia koa	1,374	
Albizzia moluccana	1,300	
Grevillea robusta	3,947	
Melaleuca leucadendron	1,274	
		7,895 trees

Nonou Forest Reserve

Acacia dealbata	135	
Albizzia moluccana	1,155	
Araucaria excelsa	68	
Casuarina equisetifolia	487	
Eucalyptus citriodora	1,000	
Eucalyptus robusta	2,282	
Grevillea robusta	28,741	
Spondias lutea	917	
		34,785 trees

Puu Ka Pele Forest Reserve

Acacia koa	488	
Eucalyptus rudis	810	
Grevillea robusta	13,114	
		14,412 trees

2. Planting Maintenance:

A total of 174,944 trees from previous plantings throughout the various reserves was hoed free from grass, weeds, and brush. A large part of our plantings has been carried on in areas covered with heavy brush and scrub growth; other areas are subjected to heavy rainfall making it imperative that the young trees be cared for at least once every 6 months in order that they may make a normal growth.

3. Erosion Control:

A number of eroded areas and gullies are to be found on reserve lands formerly used as range for livestock. These are usually of no great area but efforts have been concentrated towards planting them with suitable trees which will survive under trying conditions and check further erosion. Trees planted in these areas are spaced 6 x 6 feet to promote rapid closing-in. The Eucalyptus robusta, Casuarina glauca, Grevillea robusta and Acacia dealbata have proven themselves to be of great value in erosion control. A number of photographs included with this report show the growth and results obtained by planting these species on eroded areas.

During the period a total of 4,840 square yards of eroded gullies was sloped and planted with 1,200 trees. In addition 33,880 square yards of gully plantings were maintained within the Nonou Forest Reserve.

4. Truck Trails: (Construction)

(a) *Na Pali Kona Forest Reserve*		
Kokee CCC camp	.1 mile	
(b) *Lihue-Koloa Forest Reserve*		
Kalaheo plantings	.5 mile	
	——	.6 mile

5. Truck Trails: (Maintenance)

(a) *Na Pali Kona Forest Reserve*		
Kokee—Kumuwela road	5.0 miles	
Kokee—Camp No. 3 road	.6 mile	
Kokee—Camp No. 4 road	.3 mile	
	——	5.9 miles
(b) *Moloaa Forest Reserve*		
Kilauea Arboretum road	.1 mile	
(c) *Lihue-Koloa Forest Reserve*		
Kalaheo plantings	.2 mile	
	——	.3 mile

6. Foot Trails: (Construction)

(a) *Moloaa Forest Reserve*		
Fence line trail	1.4 miles	

(b) *Nonou Forest Reserve*

Fence line trail........................ 1.0 mile

(c) *Puu Ka Pele Forest Reserve*

Fence line trail........................ .7 mile

——— 3.1 miles

7. Foot Trails: (Maintenance)

(a) *Moloaa Forest Reserve*

Fence line trail........................ .4 mile

(b) *Nonou Forest Reserve*

Fence line trail........................ 2.0 miles

(c) *Kealia Forest Reserve*

Anahola fence line trail........................ 2.9 miles

(d) *Lihue-Koloa Forest Reserve*

Wahiawa planting trail........................ .6 mile

——— 5.9 miles

8. Horse Trails: (Construction)

(a) *Kealia Forest Reserve*

Anahola River trail........................ 1.0 mile

(b) *Na Pali Kona Forest Reserve*

Halemanu Ridge trail........................ 1.1 miles
Waininiua Ridge trail........................ .4 mile
Puka Ohelo Ridge trail........................ .5 mile
Puka Ohelo Kalalau trail........................ 4.5 miles

(c) *Puu Ka Pele Forest Reserve*

Fence line trail........................ 4.0 miles

——— 11.5 miles

In addition to the new horse trails completed, preliminary lines totaling 7 miles were laid out and partially cleared to be developed into horse trails during the ensuing period.

9. Horse Trails: (Maintenance)

(a) *Na Pali Kona Forest Reserve*

Haena-Kalalau trail........................ 4.4 miles
Waininiua trail........................ 1.0 mile
Halemanu Ridge trail........................ .8 mile
Halemanu Lookout trail........................ 5.3 miles
Halemanu Canyon trail........................ 3.0 miles
Kanalohuluhulu-Puka-Ohelo trail........................ 4.0 miles
Nualolo trail........................ 7.5 miles
Milolii trail........................ 2.0 miles
Milolii-Makaha trail........................ 1.0 mile

Alakai Swamp trail........................	1.0 mile
Malua-Popoki trail	.5 mile
Makaha trail	2.5 miles
Kauhau trail	2.0 miles
Kopiwai trail	1.1 miles

(b) *Kealia Forest Reserve*

Anahola River trail........................	2.2 miles	
	——	38.3 miles

10. Minor Roads: (Maintenance)

Na Pali Kona Forest Reserve

Kokee	3.2 miles	
	——	3.2 miles

11. Foot Bridges:

One foot-bridge 4 x 40 feet was constructed along a foot trail across a deep ravine at Halemanu, Na Pali Kona Forest Reserve, eliminating a detour of approximately one-half mile.

12. Structures:

A 10 x 16 glass-roofed, seed-germinating house was erected at the Kalaheo Nursery. Previous to the construction of such a building young seedlings were raised in flats out in the open. During the rainy season the mortality of the tiny seedlings was very high, greatly handicapping nursery production.

13. Dwellings: (Improvements)

Improvements were made to the Kanalohuluhulu Ranger Station adjacent to the Kokee CCC camp by covering the exterior walls with heavy building paper and shingles. These improvements will tend to keep out the cold and make the building more liveable during inclement weather.

14. Eradication of Plant Pests:

Approximately 10 years ago a few plants of the Himalaya blackberry were introduced to Kokee and planted there by a lessee of one of the Kokee camp sites. Soil and climatic conditions were evidently ideal for the plant as it grew luxuriantly and soon began to spread by root runners until it has covered a large area forming an impenetrable mass. Seeds of the fruit have been scattered by birds and new plants have been found growing some distance from the mother plant.

To eliminate this plant it has been necessary to cut off all growth above ground and then dig and remove all roots. Young shoots which may appear from roots left in the ground are being sprayed with diesel oil. By this method it is hoped that this pest will be eliminated in due course of time.

15. Nurseries:

During the past six months this work continued at both the Lihue and Kalaheo Nurseries. Six CCC men were employed in this work in addition to the regular

nursery personnel. It has been necessary for both nurseries to enlarge their areas to care for the increased output. Thirty new plant benches were constructed at the Kalaheo Nursery and a 10 x 16 glass-roofed, seed-germinating house was also constructed to care for the young seedlings.

A total of 197,722 seedlings and rooted cuttings was started at both nurseries during the period.

Forest Fires

In the Na Pali Kona Forest Reserve at Kokee four fires were found in early stages of burning and were extinguished before any appreciable damage was done.

Equipment

To date our trucks and station wagons have covered a distance of 135,913 miles. Five Model BB Ford trucks and one Model B Ford station wagon have completed 18 months service and are still in good running order. At the start of the Kokee camp three additional Ford V8 1½-ton trucks were purchased along with 2 Ford V8 station wagons and one Chevrolet ½-ton pick-up truck. Accurate records have been kept on the operating costs of all vehicles, including gasoline, oil, service, repairs, tires, and tubes. The following tabulation shows the operating cost per mile of each vehicle for the past six months.

Station Wagons

CCCTH-No.	Model	Cost Per Mile
K-27	Ford Model B	$ .037
K-56	Ford V8	.01
K-57	Ford V8	.01

Trucks

CCCTH-No.	Model	Cost Per Mile
K-28	Ford Model BB	$ .039
K-29	Ford Model BB	.051
K-30	Ford Model BB	.041
K-31	Ford Model BB	.032
K-32	Ford Model BB	.041
K-58	Ford V8 BB	.019
K-59	Ford V8 BB	.018
K-60	Ford V8 BB	.018
K-61	Chev. ½ Ton	.009

The average cost of gasoline per gallon during the past six months was $ .14, and of lubricating oil, $ .35½ per gallon.

Photographs

At the conclusion of this report photographs are attached showing the various projects, nature of topography, forest cover, etc.

KOKEE CCC CAMP

BY FRANK COX, DIRECTOR

The CCC camp on Kauai is located at Kokee within the Na Pali Kona Forest Reserve at an elevation of 3,640 feet. The Na Pali Kona Reserve covers an area

of 60,310 acres of which 40,420 acres are government land and 19,890 privately owned. The Puu Ka Pele Forest Reserve which borders the Na Pali Kona Reserve a short distance from the camp contains an area of approximately 4,800 acres. The two reserves form a large part of the watershed which supplies water to the sugar plantations, towns, and other interests located on the island. The sugar plantations have spent vast sums developing the water resources within these reserves and draw each day for irrigation purposes and domestic supply, several hundred million gallons of water.

The famous Waimea Canyon, which is a miniature of the Grand Canyon, is located within this region, as is Mt. Waialeale known as one of the wettest spots in the world, having an average annual rainfall of 400 inches.

A portion of the Na Pali Kona and Puu Ka Pele Reserves has been set aside by the government for camp sites. These are leased at a nominal figure. To date there are approximately 100 summer homes located within the Kokee and Puu Ka Pele Regions. All lessees are subject to the rules and regulations of the Territorial Board of Commissioners of Agriculture and Forestry.

The field projects of the Kokee CCC camp are confined to the area within the two reserves. The work already accomplished and work contemplated by the CCC in this region will not only directly benefit the sugar and interests located on the Island in time to come but will make Kokee and Puu Ka Pele a center of tourist attraction by reason of the roads and trails which are being constructed to the various points of scenic interest with which the area abounds.

Work of clearing the camp site started March 4, 1935. The site was cleared of all growth and graded to make room for the various structures. Construction commenced May 17, 1935, and an average force of about 16 civilian carpenters was employed until July when the force was reduced until completion on August 16, 1935.

Buildings

A total of thirteen buildings was constructed in the following order:

1. Three barracks, 36 x 50, as quarters for the enrollees. Latrines are located in the rear of each and the barracks are separated lengthwise by a partition about four feet high. On either side of this partition and along each side of the buildings, lockers have been provided.

2. A kitchen and mess hall, 36 x 75, which also houses the cooks, their latrine and bath and a small storeroom.

3. A recreation hall, 30 x 62, in which a small canteen is also located.

4. A bath and wash house, 12 x 34.

5. A cooler for fresh vegetables was constructed near the kitchen, measuring 12 x 12, and a storeroom, 12 x 14.

6. The foremen's quarters in a separate building, 18 x 32, contains their latrine and bath and a locker for each of the three foremen and two mechanics. It is roomy and comfortable except that it has no ceiling. This means that it is rather cold and permits myriads of bugs and insects to enter under the eaves as it is practically impossible to make a close joint with a galvanized iron roof.

7. The office for the camp Director, project Superintendent, the Quartermaster, also the Quartermaster's storeroom and dispensary, measures 14 x 40, and is ample for the needs of the camp.

8. A cottage containing a bath and latrine and three rooms, 10 x 12, for the above three executives is comfortable and entirely satisfactory.

9. A garage, 40 x 60, in one end of which two tool rooms were constructed. This building is of ample capacity but the drainage around it is poor. Its roof should be guttered. The drainage is being improved as opportunity offers.

10. A small structure to house the two electric light plants—one a small, second-hand Kohler, is used during the day and supplies power for the refrigerator only; the other, a new Delco which handles the load satisfactorily. There is also a small structure, 12 x 14, for the storage of gasoline and oil.

All this construction is of 1 x 12 S1S with battens, T & G floors, with the exception of the garage and outbuildings; and all have corrugated iron roofs; only the cottage for the executives and the storerooms have ceilings. The workmanship throughout is excellent.

Considering that this is a temporary camp, the barracks are very satisfactory. An additional twenty men can be accommodated without any crowding and in an emergency, at least fifty additional men could be quartered.

The mess hall is somewhat larger than necessary and the kitchen is a trifle crowded. An amount has been set aside to cover alterations. It is believed that the kitchen can be enlarged without any expenditure for material. Most of the labor needed could be furnished by the enrollees if this is permissible. However, this alteration is not urgent and it is recommended that it go over to a future period, and, if possible, the amount set up be devoted to the improvement of the water system which is taken up in a later paragraph.

The recreation hall is admirably suited to the needs of the men. There is ample seating accommodations and tables; a large fireplace which is an actual necessity, not an extravagance, as without it, provision would have had to be made for heating the barracks; plenty of reading matter; a victrola and a piano which were donated to the camp by interested residents.

The whole camp as conceived and carried to completion is giving satisfaction and reflects wise and careful planning.

However, it seems certain that some further provisions must be made for heating during the winter months. The mess hall, foremen's quarters, office, and executives' quarters are without heat of any kind. It is believed that five portable kerosene heaters would solve the problem. At this location the temperature at nights during the winter months often drops close to freezing.

Water System

A pumping plant is located about 245 rods from the camp. Water is pumped from a stream to three 5,000-gallon redwood tanks, a distance of approximately 460 feet with a rise of about 126 feet. It then flows by gravity through a 2-inch pipe to the camp, a distance of about 3,600 feet, with a drop of 66 feet more or less.

Although this season has been the driest in years, the water supply has held up remarkably well, although on several occasions it was dangerously low. The plant consists of a 1½ horse power Fairbanks-Morse gas engine and a belt-driven Typhoon pump. This plant runs on an average of from 8 to 12 hours per day, and while in operation, works at practically full capacity. No piece of machinery can stand this severe strain very long.

Camp Grounds

All the camp grounds are graded or filled and wash badly in wet weather. Grass for planting was donated shortly after the camp was occupied, but as the season was extremely dry, it never took root. A second lot was secured and planted and it is doing well. As yet, it offers little resistance to washing. None of the buildings are guttered, and as the rains of late have been heavy, the washing for a time was serious. Now it is under control through ditching. This work was done on the men's own time. Over a thousand shrubs and plants have been planted about the camp grounds and buildings in an effort to make the camp as attractive as possible.

Miscellaneous

The camp was occupied on July 8, 1935, on which date 43 men were enrolled. Enrollments continued throughout the month and on July 31 there was a strength of 94. On August 21 the full authorized strength of 100 was attained and it has remained at this figure to the end of this period.

Racial Classification

Japanese	25	Chinese	3
Portuguese	17	Filipino	3
Puerto Rican	13	Puerto Rican-Spanish	3
Hawaiian-Chinese	11	Spanish	2
Hawaiian	9	Hawaiian-Spanish	1
Hawaiian-Caucasian	8	Filipino-Spanish	1
Hawaiian-Japanese	3	Negro	1
Total	100		

This mixture of races is no bar to their mingling in the most friendly manner. There has been only one minor fight and that occurred between men of the same race. To date, there has been no appearance of shirking or malingering. The men do their tasks cheerfully with a minimum of complaining and are always ready and eager to engage in sports as soon as their day's work is over.

The only complaint regarding food was made about the field lunches furnished during the early days of the camp before the kitchen force had been properly organized. There has been no further complaint. The menu has been constantly improved and that it is ample is proven by the fact that every man has gained in weight from a few pounds to as much as twelve. Providing prices do not rise too much, the ration allowance is ample.

The conduct of the men while on leave has been good. Only one man has gone A.W.O.L. and not a single man has returned from home under the influence of liquor.

Men retained for strictly camp duties number thirteen. While their duties may be somewhat more pleasant than those on field duty, they are practically all men of special training, and at times are hard put to keep their work up to date. It is hard to see how the camp could be run efficiently with a less number. During the month of July, the number of men retained for other than routine camp duties averaged 13.9. The men were at work building up a wood supply. For August, this was reduced to 9.6, and for September, to 3.6.

The general health of the men has been on the average, good. There has been no serious sickness or accident. The most common complaints are colds and sore throats. There has been quite a number of minor accidents in the fields and on account of sports; but accidents from both these sources are diminishing.

The supervisory personnel have without exception rendered honest, intelligent and conscientious service.

ATHLETIC AND RECREATIONAL ACTIVITIES

BY KURT NYSTROM, QUARTERMASTER AND RECREATION OFFICER

Baseball: On August 25, 1935, a meeting was called for the planning of the CCC baseball team. Fourteen players were picked. George Ana was elected captain and third baseman and David Johnson, one of our mechanics, was elected to coach the team. Mr. Johnson was particularly well suited for this task, having been a prominent baseball player in his youth.

All baseball practice was held on the CCC camp home field. The field was levelled off by volunteers after working hours. The players have been practicing diligently and enthusiastically.

Five games were played during the month of September and I am sorry to report that of the five games played, only one was won, score, 8 to 5 in our favor. The fourth game was a close one, our team losing 6 to 5. However, I believe that a change of altitude and climatic conditions should be taken into consideration. During the games played, the heat in the Kekaha and Waimea districts was terrific. We hope that with a little more practice, we shall be able to show better results in the ensuing season.

The baseball team lost a number of good players when our football team was formed.

Five baseball bats and 12 baseballs were purchased from the profits of our canteen. After each game the teams were treated with soda water purchased through the canteen fund. The camp has been furnished, through government funds, with one catcher's mitt, one body protector, one face mask, one first base mitt, seven fielders' gloves, seven baseball bats, and twelve baseballs.

Basketball: The first meeting for the plans of the basketball team for the CCC camp was held August 23. Twelve members of the team were elected. Arnt Anerson, one of our mechanics, was appointed manager of the team. A field

captain is elected before each game. The first practice of the basketball team was held in the Waimea Community Hall on Wednesday, August 28. Future practice is to be held weekly on Wednesdays and Fridays until the league opens.

The present equipment of the team is a basketball purchased through the canteen at a cost of $6.38. Additional equipment is required, such as, basketball shirts and trunks and an entrance fee of $17.50 must be paid for the use of the Hall and as an entrance fee into the league. The estimated cost for additional equipment and fees is $45. The schedule for the games has not yet been completed. No games have been played but a scrimmage game with the Waimea Japanese team was played Friday, September 13. The score was 68 to 17 in our favor. Excellent floor work and frequent baskets have placed the team in a favorable position.

The team ought to have an excellent chance in the coming games.

Football: A meeting was held on September 16, 1935, to form our CCC football team. Twenty-eight players including two rub-down boys and a water boy and one timekeeper were elected. Our team plays barefooted and has entered a 125-pound football league.

All practice is held at our home field every afternoon after working hours. The boys have shown a spirit and an enthusiasm which is quite gratifying. Two games have been played and won. The score of the first game was 13 to 6 and the last game was a very close game with the score 6 to 5. Three more games will be played before the season is over.

It is a keen pleasure to report the splendid team work displayed and the remarkable results obtained when you consider the fact that our team won its first game against experienced and seeded players. Our outstanding players are hard to pick as the team work and cooperation is excellent.

I wish especially to mention that Samuel Smith Jr., one of our foremen and my right-hand man in athletics, has done excellent work and has proven himself a most loyal and efficient co-worker.

Future needs for athletic equipment will, as far as we are able, be taken care of by a combined canteen and company fund.

Recreational Activities

Glee Club: Our Glee Club was organized September 10, 1935, and consists of the following singers:

1. John Kamanuwai, Leader and Bass
2. Samuel Naumu, Tenor
3. Moses Gardner, Tenor
4. Abraham Huddy, Tenor
5. Abraham Williams, Baritone
6. Benjamin Paik, Bass
7. Edward Hilo, Tenor
8. John Akana, Bass
9. David Hopa, Baritone
10. Alfred Au, Baritone

The Glee Club has already been able to perform and to show their ability in front of invited speakers. Further practice will still more improve their singing.

Orchestra: Our string orchestra was organized August 25, 1935, and consists of the following:

1. William Abreu, Leader and Steel Guitar
2. Joseph Chu, Guitar
3. Benjamin Paik, Tenor Guitar
4. John Kamanuwai, Guitar
5. Joe Kaneakua, Ukulele
6. Samuel Naumu, Guitar

Like the Glee Club, our Orchestra is doing excellent work and has also been displaying their talents in front of visiting speakers. Our Orchestra will also be used for playing at our own dance which has been planned for the camp in the future.

Moving Picture Shows: The enrollees of the camp are privileged to attend one moving picture show per week. Usually Friday evening is reserved as a movie night.

The owners of Kekaha Theater and Waimea Theater have shown a fine spirit of generosity in allowing the camp 25 per cent of the collections on the ticket sales, which has been highly appreciated by all concerned.

Camp Canteen

Our camp canteen was started August 22, and the net profit from this short period, August 22 to August 30, 1935, amounted to $13.61. The month of September showed a net profit of $44.12.

All profits derived from the canteen will be used to purchase athletic equipment and eventually finance our dance. It is gratifying that our canteen, small though it is, shows such good profits.

Benefit Dance: A benefit dance is in prospect and will take place on October 26 at the Waimea Community Hall. All profits derived from this dance will be used to purchase equipment for our football team.

Albert W. Duvel, *Associate Forester.*

CCC Camp—Kokee.

Sub-Camp—Hanakapiai, Haena-Kalalau Trail.

Horse Trail, Haena-Kalalau.

Horse Trail, Haena-Kalalau.

Na Pali Coast along Haena-Kalalau Trail.

Horse Trail, Haena-Kalalau.

Horse Trail, Haena-Kalalau.

Horse Trail, Haena-Kalalau.

Horse Trail, Kokee.

Horse Trail, Kokee.

Horse Trail Construction, Halemanu-Kokee.

Truck Trail completed, Kokee.

Acacia Koa, Lihue-Koloa Reserve, age 14 months.

Eucalyptus Robusta, Lihue-Koloa Reserve, age 12 months.

Melaleuca Leucadendron, Lihue-Koloa Reserve, age 14 months.

Acacia Dealbata, Lihue-Koloa Reserve, age 15 months.

Grevillea Robusta, Lihue-Koloa Reserve, age 12 months.

Eucalyptus Robusta, eroded area, Lihue-Koloa Reserve, age 15 months.

Albizzia Moluccana, Lihue-Koloa Reserve, age 12 months.

"Uluhi" Fern closing in on fence line and road, Lihue-Koloa Reserve.

A Brief Resume of Papers Presented to the Agricultural Section of the Fifth Congress of the International Society of Sugar Cane Technologists

By R. J. Borden

A short review of some of the papers that were presented before the Agricultural Section of the International Society of Sugar Cane Technologists at its fifth congress held in Brisbane, Queensland, Australia, August 27 to September 3, 1935 is here presented.

The meetings which convened under the leadership of Dr. H. W. Kerr, Director of the Queensland Bureau of Sugar Experiment Stations, were attended by men whose names are familiar to many of us, and among those present at the reading of the various agricultural papers were the following:

M. S. Moody-Stuart	(British West Indies)	W. J. Maze	(Hawaii)
M. A. del Valle	(Puerto Rico)	W. P. Alexander	(Hawaii)
Dr. P. C. Bolle	(Java)	R. J. Borden	(Hawaii)
Dr. O. Posthumus	(Java)	A. F. Bell	(Australia)
H. W. Dodds	(South Africa)	Dr. A. J. Gibson	(Australia)
R. G. T. Watson	(South Africa)	H. F. Clarke	(Australia)
T. S. Venkatraman	(British India)	C. R. Von Stieglitz	(Australia)
L. Hirachand	(British India)	B. Tapiolas	(Australia)
W. E. Dickinson	(Cuba)	D. S. North	(Australia)
J. Carreras	(Peru)	K. R. Gard	(Australia)
W. S. Taggart	(Louisiana)	E. J. Barke	(Australia)
Dr. C. A. Browne	(Washington, D. C.)	N. J. King	(Australia)
Dr. E. W. Brandes	(Washington, D. C.)	D. L. McBryde	(Australia)
Dr. J. Matz	(Washington, D. C.)	F. E. Clarkson	(Australia)

"Report of the Committee on Labor Saving Devices:"—by W. J. Maze

This report covered the latest developments in machinery and methods being used in various sugar-producing countries to economize on the labor involved. Special mention is made of the use of the Gyrotiller and of the Rotary Hoe, operated by large Diesel tractors, to prepare fields for planting. For land ditching, the Sudan Ditcher is available, while for leveling the land, we have elevating graders and automatic scrapers which can move a lot of soil economically. Planting machines, both small and large, and of many designs are extensively used. Weed control by mechanical means has brought out many designs of cultivators—the spring-tooth type, the disc type, the rotary hoe, and the spinner—all finding their adherents. Chemical weed control has its place but is generally considered somewhat costlier than mechanical means. The use of the siphon pipe to speed irrigation is mentioned. The rather slow development of good fertilizer distributing machinery is cited. The application of filter cake by further diluting it with water so that a filter cake sludge can be pumped through slip-joint pipe to the desired place in the field, offers a cheaper way to distribute this by-product. The more recent developments in cane

harvesting machines are discussed; the perfect machine is still to be found. Mechanical cane loaders are highly successful. Transportation of cane by motor trucks fitted with semi-trailers may offer an attractive low cost operation for this part of the field work.

"Caneland Cultivation in Queensland:"—by N. J. King

Disc plows which are designed to plow under green manures and crop residues, have a piece of spring steel attached that compresses the trash while it is being cut by the sharp discs. In general, the land is plowed three or four times before planting. Often a "grubber" or subsoil knifer is used where the subsoil is compact. The rotary hoe is popular for destroying old stubble, and it has also been used to chop trash and tops prior to plowing them under. Tandem disc harrows are used between plowings. The smaller horse-drawn planting machines drop and cover the seed in a furrow that has been previously opened with a double moldboard plow; the larger planting machines drawn by a tractor open the drill, drop the seed and cover it. Fertilizer attachments are fitted to some of the planting machines.

Cultivation of plant cane has for its objective the elimination of weeds while they are small, and the avoidance of hand hoeing. A straddling disc implement fitted with a rake attachment for cultivation in the cane row is quite generally used. Plowing with a small plow and following with a "spinner" does an effective job. Small interspace rotary hoes are available.

When ratooning is practiced, trash is in some instances burned and thereafter tandem disk harrows are used to mulch the surface soil and to destroy the uppermost eyes of the cane stubble (which ensures a ratoon crop that originates from the lower dormant buds). The stubble-shaver may be used to level the land where cane rows of the plant crop have been ridged or hilled up too high. Where soil moisture is adequate, the stubble is off-barred; during dry weather the grubber is preferred for putting the soil in condition for rapid development of young ratoon roots. Where trash is not burned, it is generally rolled into alternate interspaces, either by hand or by a side-delivery rake.

"Gyrotilling at Aguirre, Puerto Rico:"—by A. L. Foss

This paper includes a description of the work which the gyrotiller can do and is doing in Puerto Rico, and a report of its operating costs. The author states "our experience with the gyrotiller is very favorable in that it does the work for which it was intended and at a very cheap cost."

"Symposium on Methods of Maturity Determination:"

A. *In Barbados*—by G. P. Stevenson

Maturity experiments are conducted at two stations which represent the low- and high-rainfall regions respectively. From three to eight seedlings and two standard varieties are included each year. The randomized block layout is employed, each variety being replicated 18 times. Each plot comprises 16 stools, the test is harvested at three periods during the crop season—early, medium, and late—and six

plots are cut at each harvest. Weights are obtained in the field and the numbers of sound and rotten canes of four arbitrary age-classes recorded. Sample bundles of 100 pounds of cane from each plot, made up of canes of the four age-classes in the ratio in which they occur in the field are milled to determine sucrose in juice. The work results in the allocation of new seedlings to their most favorable environment and the recognition of early- and late-maturing varieties.

B. *In South Africa*—by H. H. Dodds

The principal canes are sampled and tested for purity and sucrose, and also for the reducing-sugar ratio, at intervals of one month, starting in April, which is the beginning of the ripening season.

The hand refractometer has not been found reliable.

C. *In Queensland*—by H. W. Kerr

Ten sticks of cane per field, selected at random, were collected at two-weekly intervals. These sticks were divided into three equal lengths to make three samples for crushing. The juice was analyzed for Brix and polarization. At maturity, the Brix of the juice from the top and butts is practically identical and about one unit below that for the middles. When deterioration supervened, the Brix of the butt declined most rapidly, followed by that of the middles; too often this reversal of Brix values is delayed and the cane is highly over-mature before it is detected. Small analytical discrepancies often cause erroneous conclusions.

The polarization determinations followed the Brix values very closely, although the range between extreme values for several sections of the stalk was greater. Over-maturity is immediately reflected in substantially reduced polarization values. Polarization is a better criterion than Brix.

Reducing sugars are the most reliable single value for estimating the state of ripeness of the crop. The range of variation from immature cane to maximum sugar content is practically 100 per cent and the value decreases from 5 per cent to 0.1 per cent. A well-defined minimum value, uniform for all sections of the stick, is recorded at maturity. Over-maturity is revealed by a sudden and substantial rise in the reducing sugar content of the juice from the butt sections.

Dr. Kerr presents the details of a rapid and accurate colorimetric method for determining reducing sugars, and a formula by which the sugar content may be estimated from the Brix and reducing sugars. He suggests that sampling may be confined to the top and butt sections only.

D. *In India*—by B. Viswa Nath

The top/bottom ratio, with a suitable sampling technique, is generally satisfactory. The basis of this ratio concept is that as the cane ripens, the concentration of total solids in the juice of the top and bottom halves of the cane tends to approach unity. Since under field conditions it is the practice to top ~~a few~~ joints above the highest dead leaf, maturity is indicated when the top/bottom Brix ratio is 0.95. With over-ripeness, the ratio increases beyond unity.

The biggest sources of error are the nature and size of the sample and the expression of the juice. The plots are sampled at the rate of 60 to 80 canes of each variety, selecting *whole* clumps from equidistant spots. Each cane is cut into halves, roughly, and the bottom and top halves crushed separately, care being taken to avoid large variations in the feeding of canes to the mill and in the pressure of the crushing rollers.

"Cane Trash and Soil Organic Matter:"--by C. R. von Stieglitz

The experiments reported were conducted with three different soil types, with and without additions of cane trash, in pots under controlled conditions. After a decomposition period of 10 months, the actual gain in terms of available moisture due to trash treatment is 17 per cent. The reduction in "apparent density" and "volume expansion" on wetting are effects of the trash. During the decomposition, 54 to 71 per cent of the carbon was lost as CO_2. An increase in available phosphoric acid was recorded for the trash treatments, and the proportion of added soluble phosphate that was fixed by the trash-treated soil was less. Increased amounts of calcium and magnesium in trash-treated soils were greater than amounts added in the trash. Trash did not cause increased acidity, in fact, the reverse was true. There was an enormous increase in the count of soil microorganisms due to the presence of trash.

"Symposium on Methods of Selecting Seedlings:"

A. *In Barbados*—by A. E. S. McIntosh.

Of the 20,000 seedlings potted, 10,000 are planted-out in the field. Selections have been made from these at 10 to 12 months, but new plans call for this to be done at 15 to 17 months. Progeny of crosses, which have shown a high percentage of good seedlings in the past, are harvested twice during the crop—early and late. Those with satisfactory weights are divided into two bundles, one of which is milled; from the data thus obtained, about 10 per cent of the canes are retained; the other bundle furnishing the seed for planting in multiplication plots.

B. *In Puerto Rico*—by R. L. Davis

Preliminary selection of true hybrid seedlings is made from the germination flats. Those chosen go into the field nursery, being planted in groups of four on the corners of 6-inch squares, spaced one foot apart in rows that are 2 feet apart. At the age of three and one-half months, the best one of each 4 is chosen and the others discarded. The best 5,000 to 10,000 seedlings in this primary nursery are planted in secondary nurseries following the same "planting square" system, but with wider spacing, i. e., planted on the corners of a 2-foot square with the squares spaced 4 feet apart each way. A secondary elimination is also made so that only one seedling in 4 is retained. Final elimination is made at maturity on the basis of weights and juice analyses.

During the second year, the stooling habit and sucrose content are studied in comparison with interplanted standard varieties. During the third year, seed supplies are increased and those of promise are sent out for orientation tests. Final field trials are conducted with at least 10 replications in one-tenth acre square plots.

C. *At Canal, Point, Florida, U.S.A.*—by G. B. Sartoris

A detailed study of the agronomic characters and the use of a score card for selecting superior progenies are features of the Florida selection work. The breeding value of parents is carefully determined. The complete progenies from the best crosses are sent to the major sugar cane areas and tested for resistance to various diseases.

D. *At the Florida Experiment Station, U.S.A.*—by B. A. Bourne

Potted seedlings are set in the field four feet apart in furrows eight feet apart. This wide planting is to facilitate judging at maturity, since most of the canes are recumbent at this time. First selections are made on the basis of resistance to disease, good agricultural habits, and Brix. These go into line tests with two or more control canes on the two main soil types in Florida. When eight to ten months old, ten stalks are removed at random from each plot and milled. All high-testing types are again analyzed as a further check. This first series of analyses aims to discover the early-maturing types. Some three months later, a second series of analyses aids in locating the late-maturing forms and gives further data on the stability of sugar and purity of the early maturers. Final selection is not attempted until the varieties are judged and scored on their agricultural qualities and disease resistance. Since there are no replications, no weights are taken but an estimate of low, medium, or high tonnage is made by visual comparison with the control canes.

During the second year, single plot tests are established on the two main soil types. Weights and analyses are compared with the control canes at about 12 to 13 months of age, and corroborative evidence of the plant cane results is secured. The superior canes then go into replicated tests, wherein twelve replications of one-tenth acre plots are used.

E. *In Mauritius*—by A. Glendon Hill

About 75 per cent of the seedlings potted are planted-out, some at 1,000 feet elevation and some at 200 feet. At the age of one year the early-maturing seedlings are selected. The late maturers are selected at 15 to 20 months. In these selections, the healthier seedlings with good growth habits are chosen and tested for Brix with the hand refractometer. The better ones are cut and weighed, and selected for further trial. About one per cent are retained for this trial.

The second trial consists of comparing nine selected canes and one standard cane in 10-hole Latin Square layouts. The best canes from the second trial go into a third trial, being planted in randomized blocks, each plot of which consists of 3 rows of 7 holes each, and from which the center row only is harvested. These third trials may be ratooned if the varietal competition is not obvious. At the time of these third trials, cuttings of each seedling are planted in gummosis-resistance trials. Final field trials are designed so that the two outside rows of each plot are discarded at harvest.

F. *At the Colonial Sugar Refining Company*—by H. F. Clarke

(1) In *Fiji* seedlings are planted-out when 3 to 4 months old, being spaced 5 feet apart each way. For every 10 rows of seedlings there is a row of a standard variety. First selection is made at 17 to 18 months and is based on disease resistance and agricultural qualities. Up to 5 per cent are chosen for further planting in plots of 3 rows, 12 to 20 feet long, and one or more standard varieties are planted with them. The second selection is made at 15 to 20 months. A stool of each variety is cut every month from June to October to secure a ripening curve. The yield is estimated. Further selections are planted in randomized plot trials with one or more standard canes. These are cut at 17 to 18 months, weighed and analyzed. Border rows and end stools in the rows are excluded at harvest. The plots are ratooned.

(2) In *Queensland* the basis of selections is the same as that in Fiji. First selections are made at 13 to 14 months and those chosen go into a 12-foot row, with a standard cane to every 3 seedlings. They also go into a gum-resistance trial. The second selection is made at 12 to 13 months, on the basis of the gum-resistance trial, on total solids and polarization of small mill samples, and on vigor and growth habits. The next trial is in a plot of six 12-foot rows with a standard variety in every tenth plot. At 12 to 13 months selection is made on yield and juice quality for final testing in randomized plot trials.

G. *In Queensland*—by E. J. Barke

The basis of selection is resistance to disease. At least 100 seedlings are selected at random from all vigorous crosses and included in a "family" resistance trial.

Potted seedlings are planted-out at 3 to 4 months in rows 5 feet apart, with 3 feet between seedlings. Preliminary rejections are made at 10 to 11 months and final selection at 12 months. Selection is based on vigor and habit and on refractometer tests which must not be 2 to 3 degrees Brix below that of the standard cane. About 1 per cent of the total is selected.

In the second year, single row plots of 5 to 10 stools each are interspaced with a row of the standard cane. Complete juice analyses are secured at harvest. From the results of the second year, checkerboard observation trials are laid down. Maturity tests are conducted, and yields secured. These plots are ratooned to determine ratooning qualities. Selected seedlings go into farm trials on various soil types in their fifth year. A Latin Square or Randomized Block layout is used for these farm trials.

H. *In India*—by T. S. Venkatraman

Lists of suitable and undesirable parents are compiled from the type of hybrids grown each year. Large numbers of seedlings (100,000) are raised from the desirable crosses. These are planted in beds 12 by 6 inches apart. The more vigorous are picked out and planted as in the ordinary cultivation practice and grown for a full year. Juice analyses are made of only those which show the desirable vegetative characters; the rest are discarded.

These selected seedlings together with standard canes are then planted in 20-foot rows. Notes are kept on germination and habit, and a periodic study is made to estimate vegetative growth and root development. Periodic weighings of the above-ground parts and root dissections *in situ* are made. In selection work, canes chosen in bad years are found more useful than those selected in good years because such canes possess a wider sphere of usefulness. Juice analyses of each seedling are made at the beginning, at the end, and at two intermediate times during the crushing season. For each analysis, a *whole* row is cut and treated as a sample. The soil, manurial and other conditions of the testing areas are never allowed to be better than the prevalent conditions in the locality.

The selection work stresses attention on the comparison of new canes with the standards periodically throughout their growth; how they stand the critical periods and take advantage of favorable periods for growth. This enables selection to be made with some confidence.

I. *In Hawaii*—by A. J. Mangelsdorf

The use of a weak solution of sulphur dioxide and phosphoric acid to keep cane tassels alive is a big feature of the breeding technique in Hawaii. Male and female tassels for the desired cross are cut and transported to a protected area away from the likelihood of contamination from undesired pollen. Here, four female and six male tassels are set up in five-gallon pails that hold the solution which is changed at intervals of two or three days. Within ten days the male tassels are discarded and the females removed to a "ripening area," where they are watched until the "fuzz" is ready to harvest.

Seedlings are transplanted to flats when they are several inches tall; later, when about a foot tall, they are planted-out in the field in four-foot rows, being spaced one foot apart in each row. Selection is made at about 8 months, and cuttings of those desired are planted in a 10-foot row adjacent to 10 feet of a standard variety. This preliminary trial is harvested at 12 months and cuttings sent to the "regional stations" for further testing. Those which show promise are eventually distributed for final yield trial in replicated checkerboard plots.

In the primary selections, no yields are taken but selection is made on qualitative characteristics. Disease resistance is watched for. Brix readings are taken at each stage of selection in both plant and ratoon plots. Thus some 15 to 30 Brix comparisons of the seedling and its adjacent check or standard cane are secured, and fairly reliable conclusions with reference to sucrose are thus obtained.

"Irrigation in the Lower Burdekin District:"—by B. Tapiolas

There are 527 irrigation units operating in this district, pumping some 630 million gallons of water from sand beds which underlie the cane lands perhaps only 10 to 40 feet below the surface. By driving "spears" into this water-bearing sand and connecting a number of these "spears" to a pumping unit, it is possible to secure a good supply of water free of sediment.

Irrigation of the young cane is delayed as long as possible, due to the character-

istic nature of the soils to run together and become compacted by irrigation. In the early stages, water is applied in the cane furrow. Surface cultivation follows as soon as possible and this necessitates reshaping the lines for subsequent irrigations. As the crop develops the lines are filled in, the cane is hilled up, and the water furrows thereafter occupy the interspaces.

The length of furrows varies with the nature of the soil, and on some soils is as long as 1,000 feet. Water is taken from the supply ditches through 2 x 24-inch galvanized iron pipes at the head of each line. Three-inch applications are desirable, with intervals of 10 to 12 days when necessary.

"Drainage Methods in Fiji:"—by H. F. Clarke

Artificial drainage is essential on many lands in Fiji. The open-ditch system prevails. There is a ditch around the field that is 3 to 6 feet deep into which internal ditches, 125 to 250 feet apart, empty. Flood gates are necessary to keep tide waters out. The ditches are costly to maintain and reduce the cane area available.

Mole drains have been successfully used where the texture of the subsoil was suitable. They were effective for about 8 years, when they were deep enough to escape damage from cultivation implements. Recently tile drains have been used. These were set about 265 feet apart, about 3 feet below the surface. Generally speaking, this tile draining has not increased yields but it has made all field operations easier, eliminated the maintenance of open ditches and made 4 to 5 per cent more land available.

"Surface Drainage in the Mackay District:"—by F. E. M. Clarkson

The poorly drained lands are flat and have many saucer-shaped depressions, some 6 inches below the surrounding land level. The subsoils are relatively impervious. Stands of cane are poor and growth is unsatisfactory. Thus we find that open surface drains, 20 feet wide and deepened to the clay subsoil, are run across the lower end of the field and graded to deliver water to a main drain thence to swamp or creek. Other 20-foot drains along the headlands run with the main slope and deliver to this lower drain. Soil removed from these drains is used to fill depressions in the field. Drains are made broad and flat so that cultivation implements can cross them without difficulty. As a further precaution cane may be planted in beds that carry 14 to 18 cane lines running in the direction of the greatest slope, with 10-foot water furrows left between these beds.

"Variation Within a Clonal Population:"—by A. F. Bell

Variation in the number of stalks per stool may be due to variations in type and density of the microbiological flora, the rate of application of fertilizer, physical condition of soil, depth of cover placed over the seed piece, overcrowding by adjacent stools during growth, and variation in growth capacity within the visually equivalent seed pieces.

"Determining Theoretical Yields of Sugar in Connection with Variety Tests on the Basis of Field Sampling and Laboratory-Scale Milling Tests:" —by George Arceneaux.

Separate juice analyses must be available from each individual plot, if statistical methods are to be used to study sugar yield data. Where small plots are used and the total amount of cane is small, ordinary factory milling is impractical, hence the necessity of experimental milling equipment.

Studies on methods of field sampling indicate that best results are obtained when cane samples for milling are taken at random from the entire area of each plot after cutting.

Plots are one-fortieth acre in size and the test carries 12 replicates in a Latin Square arrangement. At harvest, 40 to 50 stalks are selected at random from each plot for milling in a 3-roll power-driven mill that gives an extraction of about 60 per cent. Individual averages based on 12 such determinations are sufficiently accurate to permit the measurement of differences of 5 per cent or more in yield of sugar per ton of cane.

"The Maintenance of First-Year Characters in New Sugar Cane Clones:"—by A. G. Hill

Weight-per-stool is probably exaggerated in first-year seedling selection and it is suggested that new seedlings be allowed to settle down for one or two seasons in order to allow exaggerated vigor to abate, and give undesirable traits a chance to appear before attempting to assess quantitative characters.

"Queensland Cane Variety Census 1934:"—by J. M. MacGibbon

This census shows the percentage of sugar tonnage obtained from different varieties grown in Queensland. Badila leads the list at 36.8 per cent, followed by M 1900 at 9.8 per cent, H. Q. 426 at 7.5 per cent, E. K. 28 at 6.8 per cent, D 1135 at 6.1 per cent, Q 813 at 5.6 per cent, H. Q. 409 at 4.9 per cent. Both Uba and POJ 2878 contribute 1.3 per cent and H 109 is down at .05 per cent.

"Report by the Committee on Soils:"—by O. Schreiner

This committee has assembled a bibliography of soil and fertilizer literature, listing all publications which have appeared in the period 1931-1933 which supplements the list presented at the Fourth International Congress of Sugar Cane Technologists.

"Symposium on Laboratory Methods of Soil Fertility Determination:"

A. *In Mauritius*—by N. Craig

The methods used are field experiments which are the basis for all other methods, and chemical laboratory methods and physiological methods in field and laboratory which are more rapid and easily performed.

Organic carbon in soil samples is determined by a modification of the method of Schollenberger. Both Truog's and Dyer's methods are used to determine phosphates. Exchangeable base is determined by the method of Bray and Wilthite.

Phosphate in the juice is determined by the colorimetric method of Denigés; potash in the juice by the Oliver method.

Details of all these methods are given.

B. *In Barbados*—by Dr. S. J. Saint

The correlations between juice and cane analyses are very high, and show that a juice analysis will be a good comparative indication of the analysis of the cane as a whole.

Approximately 62 per cent of the total potash, 53 per cent of the phosphoric acid, 41 per cent of the total ash, and 40 per cent of the nitrogen present in the whole cane were expressed in the crusher juice from a 3-roller mill that gave approximately 70 per cent juice and 30 per cent bagasse, by weight.

The report concludes that juice analyses are of little value in determining possible soil deficiencies because varieties differ in their absorption of potash from the soil, and climatic conditions affect the absorption of phosphoric acid particularly.

C. *In Queensland*—by H. W. Kerr and C. R. von Stieglitz

A modification of Truog's method for determining available phosphoric acid is described. When correlated with results of field trials, it appeared that 80 per cent of those soils showing more than 35 p.p.m. gave no significant response to applied phosphate, while 84 per cent of those with less than 35 p.p.m. showed a definite response.

Replaceable base determinations are not considered sufficiently precise as a test for potash availability. The greatest value of the method lies in its ability to indicate those soils on which potash fertilization can be expected to show negative response. Above a limiting value of 0.18 M. E., 84 per cent of the soil samples were from trials which failed to respond to potash fertilizers.

D. *Rapid Field Tests in Queensland*—by C. R. von Stieglitz

Rapid tests devised by Morgan have been used on a series of 39 type soils. The method for phosphate was not satisfactory, and it has been modified so that a better agreement is being obtained. Two well-defined groups—high and low—of potash can be differentiated by the turbidity test. Nitrate and ammonia nitrogen tests are sufficiently indicative as to be of distinct value.

"Methods Used to Determine the Fertilizer Requirements of Sugar Cane in Louisiana:"—by A. M. O'Neal and L. A. Hurst

A reconnaissance soil survey is first made in order to determine the principal soil areas, soil series, and soil types. This makes for a broader interpretation of the data obtained.

In selecting the test areas or plots for experimental purposes, a careful soil survey is made of that part of the plantation where the test is to be located. The plots are then laid out to the best advantage on the particular soil type that is to be studied. This location of different soil-type boundaries is considered essential to reliable results.

The individual plots consist of four rows and are one-sixtieth acre in area. Only the two center rows of each plot are harvested. Cane is weighed in the field and while weighing, sample stalks are drawn at random to make a 50- to 60-pound bundle that is milled in an experimental mill.

"Fertilizer Studies on Two Important Soil Types in Louisiana:"—by A. M. O'Neal, O. Schreiner, and L. A. Hurst

Results of these studies indicate the amounts of plant food for optimum yields and the best combinations of N, P_2O_5 and K_2O for the total plant food used.

"Methods Used by the U. S. D. A. in the Analysis of Sugar Cane Juice:"—by N. McKaig, Jr., and L. A. Hurst

When fertilizer experiments are harvested, a cane sample of 50 to 60 pounds of mill-length cane is crushed in the experimental mill. The juice is passed through a 1 mm. sieve and then centrifuged for 7 minutes against a force of 2,300 times gravity. This eliminates suspended material without altering the concentration of soluble materials.

Various analytical procedures are discussed.

"A Study of Sugar Cane Stalk Age Groups Under Louisiana Conditions:" by George Arceneaux

This report summarizes the results of studies conducted on shoots and millable stalks of 10 cane varieties divided into 4 groups according to their period of germination.

The rate of mortality was approximately the same for mother shoots and suckers originating before April 20 and after this date.

A definite relationship as to average weight per stalk was revealed for the different age groups. Arranged in descending order of stalk weight are (a) suckers originating between April 11 and May 29, (b) suckers originating prior to April 11, (c) suckers originating after May 29, and (d) mother stalks. Group (c) suckers averaged about 10 to 13 pounds of sugar per ton of cane less than other groups.

"Mechanical Help for Field Sampling:"—by F. D. Stevens

Platform scales are mounted on skids and hauled by a three-quarter-ton truck that carries a portable mill geared to a small engine. The scales carry a basket platform that holds about 300 pounds of cane and is easily tipped.

The use of this portable mill eliminates the hauling of ~~cane~~ samples to the mill. The selected 50- or 60-pound cane sample is crushed and a 2-pound juice sample placed in a copper cylinder for transportation to the laboratory.

"Special Three-Roller Mill Used in Experimental Field Work:"—by O. Schreiner and N. McKaig, Jr.

A description of this mill, together with comments on its efficiency, and data concerned with its comparison with a large commercial mill are given.

"Report of the Committee on Field Experimentation:"—by H. W. Kerr

The report discusses at considerable length the theoretical principles concerned with field experimentation. It calls attention to variation, and explains the frequency distribution curve and other basic facts concerned with an introduction to statistics. It discusses "Student's" method and Fisher's method, paying considerable attention to the analysis of variance and the use of the Latin Square and Randomized Block arrangements.

Such phases as the number of replications, the size and shape of plots, border effects, arrangements of plots, and the determination of plot yields and juice analyses data are also discussed.

"Plot Technique in the Testing of Sugar Cane Varieties:"—by C. G. Lennox and A. J. Mangelsdorf

An optimum plot size of one-tenth to one-fifth acre is suggested for heavy yielding canes. The effect of competition along the plot borders is far-reaching and yields on smaller plots may be misleading. Attention is needed to secure reliable averages that represent the true yielding ability. Guard rows are useful but may complicate harvesting operations and result in a loss of accuracy in plot separation.

Our efforts are aimed first at securing a reliable estimate of the magnitude of the difference in yields, and second at the error of this difference. The preferred plan is one in which the seedling plots are alternated with the standard variety, and "Student's" method of analyses is used to estimate the reliability of the yield differences obtained.

Hepialus Pharus Druce*

A moth borer attacking sugar cane in Guatemala

By Francis X. Williams

In 1934, while working with F. A. Bianchi at Finca El Salto, Escuintla, Guatemala, on insect enemies suitable for importation against the sugar cane root grub (*Anomala orientalis* Waterhouse, Scarabeidae) in Hawaii, certain other insects, injurious or beneficial, also came to notice. Among these was *Hepialus pharus,* a somber, chiefly gray-and-brown moth of variegated pattern, with very short antennae and measuring up to nearly 3 inches across outstretched wings, and the caterpillar of which—active, naked and cylindrical—was a borer in the stems of several species of plants, including sugar cane.

The work of this caterpillar was first observed in early July, in the squarish, though grooved stems of a large coarse weed of the Labiatae, or mint family, present on the edge of a sugar cane field, and in places in an adjoining pasture, growing almost in pure stands. Subsequently, other weed-plants, including a tall stout species of Compositae with large, deeply cleft leaves, and a malvaceous shrub were found attacked by this insect, while the woody stems of forest shrubs were often tunnelled by this or another species of Hepialidae. In addition, a thick-stemmed forage grass, perhaps Napier grass, was in one instance bored in a like manner. More often the borings of *Hepialus pharus* were above ground, but in weeds they occasionally extended a short distance into the roots. A weed stem several feet tall might harbor two, or even three caterpillars along its length, the entrance to each of their borings being sheltered by a soggy enclosing curtain of frass and perhaps wood particles spun together with silk. This bulging curtain sometimes completely encircled the stem at the aperture, and though not strong, probably afforded considerable protection to the caterpillar and pupa against enemies from without. A sluggish, bright red caterpillar, which was judged to be one of the Cossidae, a family also notorious as wood borers, was more rarely found. Sometimes two or more individuals were found living amicably together, in the same large-leaved Compositae weed as is attacked by Hepialus. This red borer likewise spun a protective covering over the aperture to its tunnel. It did not occur in sugar cane.

At first it appeared that two distinct species of Hepialus caterpillars affected the cane and the various weeds above enumerated. Both types of caterpillars had large roundish, dark brown heads, a reddish-brown plate on the first segment of the thorax, and smaller paler plates on the remaining segments, but the larger type of caterpillar, attaining a length of nearly 2½ inches, had a rich coffee-brown body bearing contrasting pale yellowish plates, while the smaller type was chiefly a sort of pale smoky-brown with plates also pale, but less developed. Both types transformed into pupae. Notwithstanding the differences between the two caterpillars the writer

* Thanks are due to Dr. Guy A. K. Marshall, Chief, Imperial Bureau of Entomology, London, for identifying this moth.

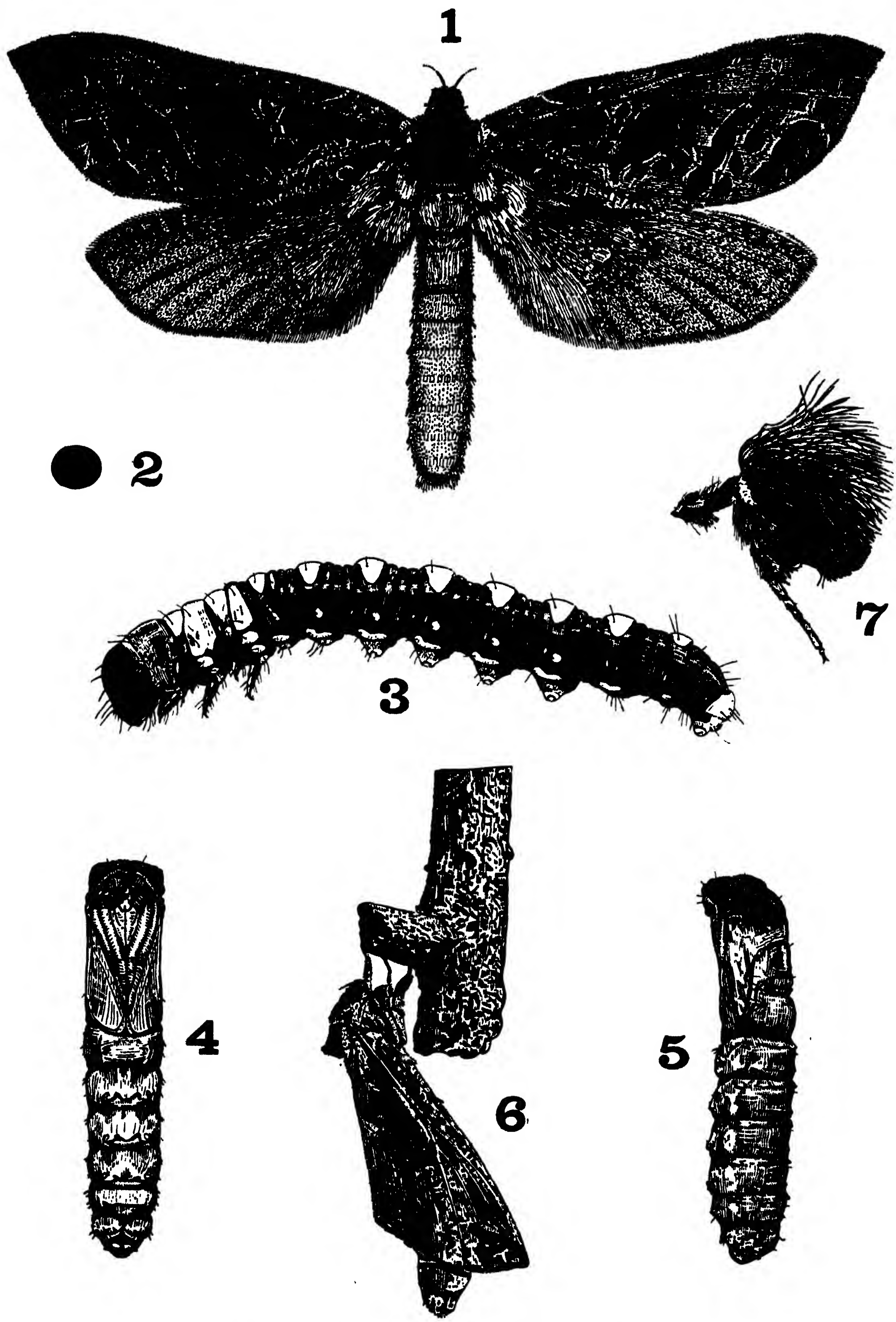


Fig. 1. *Hepialus pharus*—1. Female moth, expands to nearly 3 inches across the wings. 2. Egg; about 1/50 of an inch in diameter. 3. Full-grown caterpillar; about 2 1/3 inches long. 4. Pupa; from underside, about 1 1/8 inches long. 5. Pupa; from the side. 6. Moth at rest. 7. Hind leg of male moth.

Fig. 2. Year-old POJ cane bored and broken by the caterpillar. From an enlarged photograph.

believes that but one species, *Hepialus pharus,* was here involved. Both sorts of caterpillars were found in the weed stems and both, I believe, in sugar cane, and the moths captured in the vicinity were all *H. pharus.*

The Hepialus caterpillar is a vigorous and extremely active insect, progressing forward or backward with almost equal ease in its snug tunnel. It attacks perfectly healthy sugar cane—in the cases observed the canes were 10 to 11 months old plant POJ of several varieties and generally quite succulent. Its borings occurred chiefly in cane along the margin of the field although occasionally one was found 4 or 5 cane rows within it. The neat cylindrical, and often moist borings are commonly in the very heart of the stem and hence chiefly parallel to it until, approaching a node with its harder tissues, the course becomes one of more or less transverse curves, thus insuring almost certain breakage at that point. These borings were not observed to be very extensive; they often transversed one node, sometimes there were two caterpillars per stem, or two parallel borings in one internode, but the main length of the stem would be free from attack. These tunnels were frequently no more than a few inches to a foot above ground; in one case a boring was situated about 4 feet up the cane stem.

These borers were first noticed in newly stripped sugar cane, about the middle of July. At that time they were well grown. Some of the caterpillars pupated in August while moths were observed early in September and into October, when our chief entomological work was completed. On September 10, a search for Hepialus caterpillars in cane stems revealed only pupae. But caterpillars were still to be found in weed, and shrub stems. Perhaps the more succulent and nourishing stems of sugar cane bring the insect to maturity quicker than when in the stems of the dicotyledonous plants.

The larva seems generally to keep its tunnel clear of frass, using that material in the construction of the curtain over the opening and for plugging up any old or undesirable tunnel. Before transforming into a pupa it lines a tunnel thinly with silk and stoppers up any unnecessary extension of this chamber. This pupation tunnel may be 6 inches in length and its opening to the exterior is guarded by the usual soggy cover. Finally, the Hepialus larva casts off its skin for the last time, to become a cylindrical brown pupa, blunt at either extremity and darker there, particularly at the roughened head end. The abdomen is provided, both dorsally and ventrally, with finely toothed transverse ridges. The pupa may reach a length of 28 millimeters or more, or in excess of an inch. Even in this so-called resting stage it is capable of considerable activity and can travel up or down its cylindrical chamber by means of undulatory movements of some of the ridged abdominal segments. It is sensitive to certain changes and may back down its tunnel when exposed to light.

When the time for the emergence of the perfect insect is at hand, the pupa having worked itself to the open end of the tunnel, thrusts itself part way through the curtain of frass—if indeed the latter has not already been weathered away. Now the integument of the pupa splits apart at the head and thorax above, and the hairy moth squeezing out of this pupal fissure, suspends itself nearby to await the final development of wings and other parts. Subsequently the empty pupal skin may fall to the ground instead of remaining partly extruded from the tunnel in the cane stem.

Fig. 3. Portion of cane stem showing the caterpillar in its tunnel. From an enlarged photograph.

The moth flies early in the evening and, following the general custom of its ancient family—for the Hepialidae are a primitive group of moths—the male at least, remains on the wing for a very short time, not more than 15 minutes, as observed at El Salto. He suddenly appears at a little past 6:00 p. m. to indulge in an erratic, very swift oscillatory flight over a certain spot, as along a brush-fringed path or beside a clump of vegetation. This irregular swinging-back-and-forth, a pendulum-like flight, is for the purpose of attracting the female that is then flying about. The male is provided with curiously tufted hind legs, the glands of which, diffusing an odor, are probably a further aid in attracting his prospective mate. The female lays a large number of nearly spherical greenish-white eggs that eventually turn ebony black. They are very slightly more than 0.5 millimeter in diameter. She probably drops them here and there when in flight so that the hatching caterpillars must crawl about in search of a suitable plant in which to bore. This species like many other Hepialidae is of polyphagous habit and is thus almost sure to include among its hosts some plant that is useful to man.

The moth is kept in some control by natural enemies. Ants sometimes penetrate through the frass cover of the tunnel and attack the caterpillar. Hatched puparia of what was probably a tachinid fly were found among the remains of a Hepialus pupa in a boring in sugar cane.

Hepialid moths are of considerable interest to entomologists, largely because of their peculiar habits. The mature insect is sometimes referred to as the "hanging moth," as suggested by its position when at rest (see illustration). And because of their very rapid flight we have the name "swift moths," while the satiny-white male of *Hepialus humuli* of Europe, as it hovers over some lonely meadowland at dusk is no doubt well named the "ghost-moth."

The Fluctuations of Sugars in the Leaf Blades of the Sugar Cane Plant During the Day and the Night

By Constance E. Hartt

CONTENTS

I. HISTORICAL INTRODUCTION

Sugar Formation in Plants (Photosynthesis) Involves Numerous Problems

During what part of the day does a cane leaf contain the most sugar? How is that sugar made, and how transported to the stem? In the process of photosynthesis, or manufacture of food by the green coloring matter of a leaf with the energy of sunlight (the process upon which our entire industry and life are dependent) just what kind of sugar is made first? Is cane sugar, our essential food, the first product of photosynthesis? Or is it a simpler type of sugar, like glucose? Or is the first product a more complex substance, such as starch? What is the nature of the chemical change which results in the immediate formation of cane sugar? Those minute, oval, green bodies which are found in certain cells of the sugar cane leaf surrounding the veins are in some way the source of all the sugar and a major portion of the wealth produced in Hawaii, yet we do not even know whether they produce the cane sugar directly, or indirectly via some simpler substance such as glucose. We do not *know*, but as will be shown presently, more and more the plant physiologists of today are coming to the opinion that the first sugar of photosynthesis is glucose.

The investigation herein reported was undertaken in an attempt to answer some of the most fundamental questions in the physiology of the sugar cane plant—questions which may have a direct practical bearing upon the problems of irrigation, ripening, fertilizer applications, and other cultural practices. This investigation is not yet complete and we are by no means ready to give final answers to the questions raised; in fact this paper is written more for the purpose of raising questions than of answering them. Because of the interesting curves which have already been obtained it is thought advisable to put them on record with some explanatory material.

Sugars, Starch, and Polysaccharides are Carbohydrates

A few introductory remarks about the compounds dealt with in this report may not be out of place. It is generally considered that the substance produced by the green plant from water and carbon dioxide is a carbohydrate. A simple definition of a carbohydrate is a compound containing carbon, hydrogen, and oxygen, the last two elements in the same proportion as they occur in water. The molecule or smallest possible particle of water contains twice as much hydrogen as oxygen and the same holds true for a carbohydrate.

We are concerned with only a few of the many carbohydrates. The simple sugar which we call glucose has the formula, $C_6H_{12}O_6$. Cane sugar, or sucrose, the product turned out by the mills, is a more complex substance, that is, its smallest particle or molecule is larger than the smallest particle of glucose. The formula of cane sugar is, $C_{12}H_{22}O_{11}$. Because cane sugar has twelve carbon units, which is twice the number found in glucose, cane sugar is called a double sugar or disaccharide, while glucose is called a single or simple sugar or monosaccharide. Starch is much more complicated than cane sugar, being composed of a great many sugar-units. Starch is therefore called a polysaccharide (or multiple sugar). The exact structure

of starch is not known. There are several other very complex carbohydrates which as a whole are called polysaccharides; it is known that they differ from one another, but the exact nature of their difference is not clearly known.

There is another simple sugar often found in plants, called fructose, which has the same formula as glucose—$C_6H_{12}O_6$—but which differs from glucose in several ways. It will not be necessary to mention these differences.

Glucose, fructose, cane sugar, starch, and polysaccharides may all be used by the plant for food. Glucose and fructose, being simple sugars, require no digestion, but can be used just as they are. The others, being more complex, must be digested before they can be used by the plant.

The difference between simple sugars and polysaccharides has been likened to the difference between a single brick and a brick wall. Just as it is work to lift up bricks and build a wall, so it is work for a plant to build up the constituent simple sugars into the large polysaccharides.

Plants contain other carbohydrates besides the ones already mentioned. Cellulose, familiar as the fibre of sugar cane, is a very complex polysaccharide and is of such a nature that it can not be digested and used as food by green plants.

The terminology of carbohydrates is complicated by the fact that each kind may have several names. Thus glucose is also called dextrose and grape sugar. Fructose is called levulose and fruit sugar. Both glucose and fructose are called "reducing sugars," not because they make fat people thin, but because they reduce or change Fehling's or Soxhlet's solutions. A mixture of glucose and fructose is often called "invert sugar" because it results from the inversion or digestion of cane sugar. Glucose and fructose are also called "hexoses" because they contain six oxygen units.

Cane sugar, named from the sugar cane plant, is the same thing chemically as beet sugar. It is also called sucrose and saccharose.

Carbohydrates are Made Through Photosynthesis, Either Directly or Indirectly

Plants which contain the green pigment chlorophyll have the ability to manufacture their own food, using carbon dioxide and water as the raw materials. The source of the carbon dioxide is the air. The principal source of water is the soil. The process takes place chiefly in the leaves. Because sunlight is absolutely necessary for this process, it is called photosynthesis (or "putting together by light"). With the exception of a process of minor importance which occurs in a few kinds of bacteria, this is the only way in which carbon can be assimilated by plants. Human beings and all animals are absolutely dependent upon photosynthesis in plants for their supplies of food, clothing, many building materials and other things. We are dependent upon the photosynthetic activities of plants of past ages for our supplies of coal, natural gas, etc. The storage of the sun's energy in food in the process of photosynthesis is of primary importance, yet the mechanism of the chemical changes involved is unknown. Anyone interested in a more complete treatment of the many important problems connected with the subject of photosynthesis is referred to Spoehr (43) and Stiles (47). The problems of particular interest to the sugar planter have been discussed by Agee (1).

What Are the Opinions of Other Workers?

Few fields of plant physiology have aroused more interest than the order of the formation of the assimilates in the process of photosynthesis. Undoubtedly the stimulus to research of this nature lies in the great practical as well as theoretical importance of the question. Comparatively little attention, however, has been paid to the physiology of sugar production in the sugar cane plant. In the following paragraphs, attention will first be directed to the more important papers concerning plants other than sugar cane; subsequently the work with the plant of greatest interest to us will be reviewed.

Briefly, the question is this: What compound is the direct product of photosynthesis? That it is a carbohydrate is of little doubt. Is it glucose, or a mixture of glucose and fructose, or sucrose, or starch? What is the origin of sucrose in the sugar cane plant? Does it arise spontaneously in the process of photosynthesis? Is it formed by the condensation or union of glucose and fructose? Is it the result of a change within the molecule (or smallest particle) of starch before digestion? Or is it made by a combination of these processes?

A. Studies With Plants Other Than Sugar Cane:

1. *Starch:* Sachs (39, 40), writing in 1862 and 1864, considered starch to be the first visible product of assimilation or photosynthesis. De Vries (16) in 1878, thought the green pigment chlorophyll first formed starch, which was hydrolized or digested to glucose, the glucose migrated to the roots and there polymeryzed (or united with itself) to form sucrose. Although the production of starch in green leaves occurs very quickly upon exposure to light, which might be considered evidence that the first assimilate in photosynthesis is starch (45), yet the total absence of starch in the onion, leek, Narcissus, and several other plants renders this view improbable. We realize that plants do not necessarily carry on their life processes according to what we consider the simplest and easiest methods, but it would seem that the production of so complex a molecule as starch at one jump would be most unlikely.

Although we may thus lay aside the view that starch is the primary assimilate, the possibility of the production of cane sugar from starch remains still to be considered. Ahrens (2) found that when starch disappears under conditions of wilting of the leaves, the starch is converted into cane sugar. Schroeder and Herrmann (42) found that in wilting nasturtium leaves the cane sugar content increased at the expense of starch. That the conversion of starch to cane sugar occurs in plants thus seems well established, but the chemical mechanism of the change is unknown. Starch is a large molecule composed of a series of glucose anhydrides or units. Cane sugar, however, is composed of one molecule or unit of fructose combined with a molecule of glucose. Therefore at some stage in the conversion of starch to cane sugar allowance must be made for the production of fructose. Whether this occurs by molecular rearrangement of some of the glucose groups in the starch chain, or by a conversion of glucose to fructose after digestion of the starch, is unknown. Very suggestive, however, is the work of Hasselbring (25) concerning carbohydrate changes in Narcissus bulbs during storage. Untreated bulbs stored at 62.6° F.

were compared with bulbs heat-treated at the middle of the storage period by immersion for four hours in water at 109.4° F. In both sets of bulbs there was a gradual loss of starch during the entire storage period, with a greater loss in the treated bulbs. Simple sugars (glucose and fructose) increased gradually until about the middle of the storage period and then receded practically to the original quantity, and this increase in simple sugars was greater in the treated bulbs. However, we are at present most interested in the fact that during the last six weeks of storage coincident with the disappearance of simple sugars an increase in cane sugar occurred. Thus in these Narcissus bulbs the following series of changes seemed to occur: starch converted to glucose, some glucose changed to fructose followed by a union of glucose and fructose to form cane sugar.

Although the degredation of starch, at least occasionally, results in the production of cane sugar, it may be stated with reasonable certainty that not all of the cane sugar in plants is formed in that way. Cane sugar is made in some plants which contain no starch; and other plants, notably sugar cane, produce considerably more cane sugar than starch. Because certain varieties of sugar cane contain more starch than others, and because certain diseases and conditions of malnutrition may increase the congestion of starch in sugar cane as well as other plants, the factors affecting the conversion of starch to cane sugar in the sugar cane plant are of considerable importance. The effect of irrigation vs. withholding water upon the production of starch and cane sugar in the sugar cane plant is now being studied, using the plants illustrated on the cover of this issue, and a brief preliminary report has already been published (24).

The conclusion seems justified that starch is not the primary assimilate. Under certain conditions, as yet not fully understood, starch may be converted into cane sugar.

2. *Cane sugar:* The theory that cane sugar is the primary assimilate in green plants was proposed in 1893 by Brown and Morris (7) in their classical researches on the chemistry and physiology of foliage leaves. Before their time it had been taken more or less for granted with little or no experimental evidence, that glucose was the primary sugar. Their analyses of the nasturtium showed fluctuations in cane sugar during the day, whereas glucose remained nearly constant in amount. Their work has been widely quoted and their paper may be considered one of the most substantial foundations of the theory that cane sugar arises as the first product of photosynthesis. However, their methods have been severely criticised, both because they analyzed dried leaf powder (in which changes undoubtedly occurred before analysis), and because their methods of estimating glucose and fructose are of doubtful value. Their contentions, therefore, should not be accepted as conclusive.

Another important paper is that of Parkin (35), published in 1912 on the carbohydrates of snowdrop leaves. Parkin found the simple sugars fairly constant in the leaf during the day and the night, while cane sugar increased during the day and decreased at night, leading him to the conclusion that cane sugar is the first sugar of photosynthesis. But Parkin's results are also not conclusive, for he used air-dried leaf powder (in which considerable changes might have occurred), and he took

samples at only two times during the 24 hours, a procedure which might easily mask any real relationship between the sugars.

Probably the most important of the modern studies supporting the view that cane sugar is the primary product of photosynthesis is the series by Davis, Daish, and Sawyer (12, 13, 14) published in 1916. They were very careful with their methods, which until lately were not questioned with the exception of their method of distinguishing between glucose and fructose, which was questioned by the authors themselves. In their studies of the mangold leaf, Davis, Daish and Sawyer (12) obtained evidence that before and during translocation (or transportation of sugar from the leaf to the stem) there is an inversion or digestion of cane sugar to simple sugars, and concluded that cane sugar was thus the primary sugar in the leaf. But, as has been pointed out by Stiles (47) this conclusion is not justified, inasmuch as it is quite reasonable to assume that the simple sugars are formed first, are then changed to cane sugar for temporary storage, and later digested to simple sugars for translocation. As a matter of fact, at least one of their experiments indicates that the simple sugars are formed first; their curves obtained on September 10-11 when smoothed show an increase in simple sugar from 10 a. m. to 6 p. m. followed by a decrease until 8 a. m., whereas cane sugar showed no significant increase until 4 p. m., increasing from 4 p. m. to 2 a. m. and then decreasing. Thus in that particular experiment at least, a formation of simple sugar must have occurred before cane sugar was made.

In another paper, Davis and Sawyer (14) state that unless sucrose is the first sugar, it is difficult to see why it predominates in leaves of such different plants as potato, grape, sunflower, and snowdrop (evidently disregarding two of their own experiments with the mangold in which the simple sugars predominated in the leaves). As has been pointed out by Dixon and Mason (17), Priestly (36) and others, the difficulty of Davis and Sawyer is readily overcome by assuming that the predominance of sucrose is due to its being a temporary storage product and that the simple sugars are always the transitory forerunners of cane sugar.

The three series of studies just reviewed (Brown and Morris; Parkin; Davis, Daish, and Sawyer) are the most important and most often quoted papers concluding that cane sugar arises as the first product of photosynthesis. After a thorough consideration of these papers the conclusion seems inevitable that this theory is not well supported by evidence.

3. *Simple sugars:* The investigators suggesting that the simple sugars are the first sugars formed in photosynthesis include some who think that both glucose and fructose arise simultaneously and others who suggest that glucose alone is the primary sugar. This question is complicated by the theories of the interconversion of glucose and fructose, a process known to occur although the exact mechanism in plants is not fully understood. For the sake of simplicity, the "glucose and fructose" and the "glucose alone" papers will be considered together.

The question is, are the simple sugars formed before cane sugar in photosynthesis?

Overlooking some early papers with no experimental evidence or with doubtful methods, the first paper of importance is that of Dixon and Mason (17) who in

1916 reported microchemical tests with leaves. Simple sugars in considerable concentration were found in and near the chloroplasts (minute bodies containing the green pigment), whereas cane sugar was concentrated near the vacuoles (watery spaces in the cell surrounded by protoplasm). Dixon and Mason suggested that the rise of cane sugar in the light is not a cogent argument that it is the primary sugar. Because the volume available for simple sugars (i. e., the space near the chloroplasts) is small compared with the space for cane sugar (i. e., the large vacuoles), the increase in the percentage of simple sugars is small compared with the increase in cane sugar in the light.

Priestley (36) in 1924 after summarizing the literature concluded that the simple sugars are the primary sugars of photosynthesis. According to Priestley, the simple sugars should not be expected to fluctuate in the light and dark as much as cane sugar, since as intermediate forms they may pass over readily into many other compounds and are not themselves storage forms. His unusual contention that cane sugar might be a breakdown product in cell metabolism has not been generally accepted.

Weevers (51) studied the sugars in green and yellow portions of variegated leaves. Weevers concluded that the simple sugars are formed first because both simple sugars and cane sugar were always found in the green portions, whereas cane sugar and little or no simple sugars were found in the yellow portions. Leaves of geranium deprived of sugar by being held for a period in the dark and then exposed to the light, produced first simple sugars and later cane sugar.

Spoehr (43) in 1926 reviewed the subject of the order of formation of the sugars in photosynthesis and said, "Unquestionably it would be very helpful if it were known just what the first sugar is that is produced in photosynthesis. In the present state of our knowledge glucose fits the theoretical requirements most adequately. Yet the fact cannot be entirely disregarded that the demonstration of glucose actually being the first sugar formed is still wanting."

Some advance in this demonstration has since been made by Tottingham, by Barton-Wright and Pratt, by Bulgakova, and by Clements. Tottingham and coworkers (48) in 1926 took afternoon samplings of sugar beet leaves for eleven days and found that the percentage of simple sugars followed in general the variations in solar radiation which would be expected if the simple sugars are made by photosynthesis.

Barton-Wright and Pratt (4) in 1930 reported careful studies of hourly samplings of Narcissus leaves. They found that previously darkened plants when returned to the light formed simple sugars soon after the stomatal pores opened, and later formed cane sugar. Maxima in daily curves for simple sugars were followed by increases in cane sugar, indicating condensation of simple sugar to cane sugar. They consider their evidence conclusive, that the simple sugars are formed first and later condense or unite to form cane sugar.

Bulgakova, Giubbenet, and Liubimenko (8) in 1930 in a study of the sugar beet, found a close correlation between variations in the amount of simple sugars in the parenchyma of the leaf and the duration of light, ~~indicating~~ that the simple sugars are the first products of photosynthesis.

Clements (10) in 1930, studied the hourly variation in sugars in the leaves of the sunflower, soybean, and potato. He found that cane sugar disappeared in the leaves in the early morning (5 to 6 a. m.) and did not reappear until sometime after photosynthesis had started and only after the simple sugars had reached a certain maximum. Then as cane sugar increased the simple sugars decreased. He concluded that the function of cane sugar in the leaf is temporary storage.

Priestley (37) in 1931 in a popular review of this subject stated, "The balance of evidence at the present time would seem to be in favour of the original supposition that glucose is the first sugar to be set free in photosynthesis."

Barton-Wright and M'Bain (5) in 1932 studied the carbohydrate metabolism of potato plants and found that an increase in cane sugar in the leaf is dependent upon a decrease in simple sugars, from which they concluded that the simple sugars are formed first in the leaf and later condense or unite to form cane sugar, thus confirming their conclusions obtained with Narcissus.

Armstrong and Armstrong (3) in 1934 after a brief review of the literature on photosynthesis present the chemists' viewpoint of the relationship between glucose and other carbohydrates. They suggest that almost all other carbohydrates, including cane sugar, arise from glucose. They take as a working hypothesis the primary position of glucose and mention "the fact that the first step in plant synthesis is to produce the highly asymmetric d-glucose."

In comparing the more important references under *Cane sugar* with those under *Simple sugars,* it is interesting that the *Cane sugar* papers are dated 1893-1916, while the *Simple sugars* papers are dated 1916-1934. More and more the plant physiologists of today are coming to the conclusion that the simple sugars are the primary assimilates in photosynthesis, and that cane sugar arises from the simple sugars.

4. *The formation of cane sugar from the simple sugars:* One of the arguments most often advanced against the theory that the plant makes cane sugar from the simple sugars, is the inability of chemists to reproduce such a process in the test tube. Although many attempts have been made, cane sugar has not yet been produced artificially. A sugar which gave all the tests for cane sugar, was made by the simultaneous action of two enzymes (invertase and phosphatase of yeast) by Oparin and Kurssanow (34). This important advance awaits confirmation.

One of the great difficulties connected with the artificial production of cane sugar is the fact that cane sugar contains both glucose and fructose, and the fructose is a special form which is very unstable. Beginning with the ordinary stable form of fructose it is impossible to make cane sugar, either in the test tube or in a plant. Because the unstable form of fructose is only very fleeting in its presence in a plant it is argued that cane sugar cannot arise naturally from the simple sugars, but must be made directly in the process of photosynthesis. Now let us examine this argument; a necessary corollary is that any other naturally occurring carbohydrate in plants which contains the unstable form of fructose must have an origin similar to cane sugar. Two such carbohydrates come to mind: raffinose, a triple sugar occurring in the beet and other plants often along with cane sugar; and inulin, a polysaccharide found in the ti, dandelion, artichoke, Dahlia, and other plants. It

seems unreasonable to suppose that all three of these substances (cane sugar, raffinose, and inulin) arise as direct products of photosynthesis. Assuming that cane sugar arises in such a way leaves the origin of raffinose and inulin still to be explained.

According to Liubimenko and Rubinov (30), inulin is made from a simple sugar in the underground stem of the dandelion. They also found sucrose along with the inulin in the dandelion, and state that the role of cane sugar is not clear but that possibly it is formed parallel with inulin and serves as a reserve carbohydrate. If there is in plants a mechanism which facilitates the condensation of the unstable form of fructose in the formation of raffinose and inulin, a similar mechanism may aid in the formation of cane sugar. The necessity for a mechanism involving the formation of inulin as well as cane sugar from the unstable form of fructose has also been mentioned by Colin (11). As a matter of fact, many plant physiologists and biochemists are assuming such a mechanism to exist. According to Gortner (21) although it is still uncertain whether glucose is the primary product of photosynthesis, it is nevertheless the unit from which are derived cane sugar and many other carbohydrates. Pringsheim (38) considers that such unstable sugars as that contained in the fructose portion of cane sugar are formed preferentially as intermediate products in the natural assimilation processes. Armstrong and Armstrong (3) recognizing the, as yet, unsolved difficulty connected with the formation of cane sugar, nevertheless place glucose as the primary sugar and suggest its transformation into almost all the naturally occurring carbohydrates, including cane sugar. Steele (46) suggests that the first product of photosynthesis may be the more reactive and unstable form of fructose along with glucose. The work of Oparin and Kurssanow (34) suggests the possibility of the importance of the enzyme phosphatase as a part of the mechanism in facilitating the condensation of the unstable fructose in the formation of cane sugar.

Burkard and Neuberg (9) reported in 1934 that the monophosphates of glucose and fructose can be isolated from beet leaves, the yields being in the ratio of approximately 1:1. The abstract states that they discuss the probability of the reaction of glucose and fructose to produce sucrose in the plant, but unfortunately their complete article is not yet available in Honolulu.

Definite proof that leaves can convert simple sugars into cane sugar has recently been published by Virtanen and Nordlund (49). Using red clover and wheat and later (33) working with beans, leaves which had previously been kept in the dark for 24 hours were placed in 10 per cent solutions of glucose or fructose for a further 24-hour period of darkness. When supplied with either glucose or fructose, the amount of cane sugar produced was about 6 per cent of the dry matter of the leaves. The authors consider that this is best explained by assuming that a mutual conversion of glucose into fructose and vice versa occurs in plant tissue and that glucose and fructose unite to form cane sugar in the leaves of plants.

To sum up the work with plants other than sugar cane, what have we learned?

The most modern evidence indicates that the simple sugars are the first products of photosynthesis, and places glucose as the center of carbohydrate metabolism from which are derived almost all of the carbohydrates in plants which of course includes

THEORETICAL ORIGIN OF CARBOHYDRATES IN PLANTS

Based on Armstrong and Armstrong, "THE CARBOHYDRATES," and other sources.

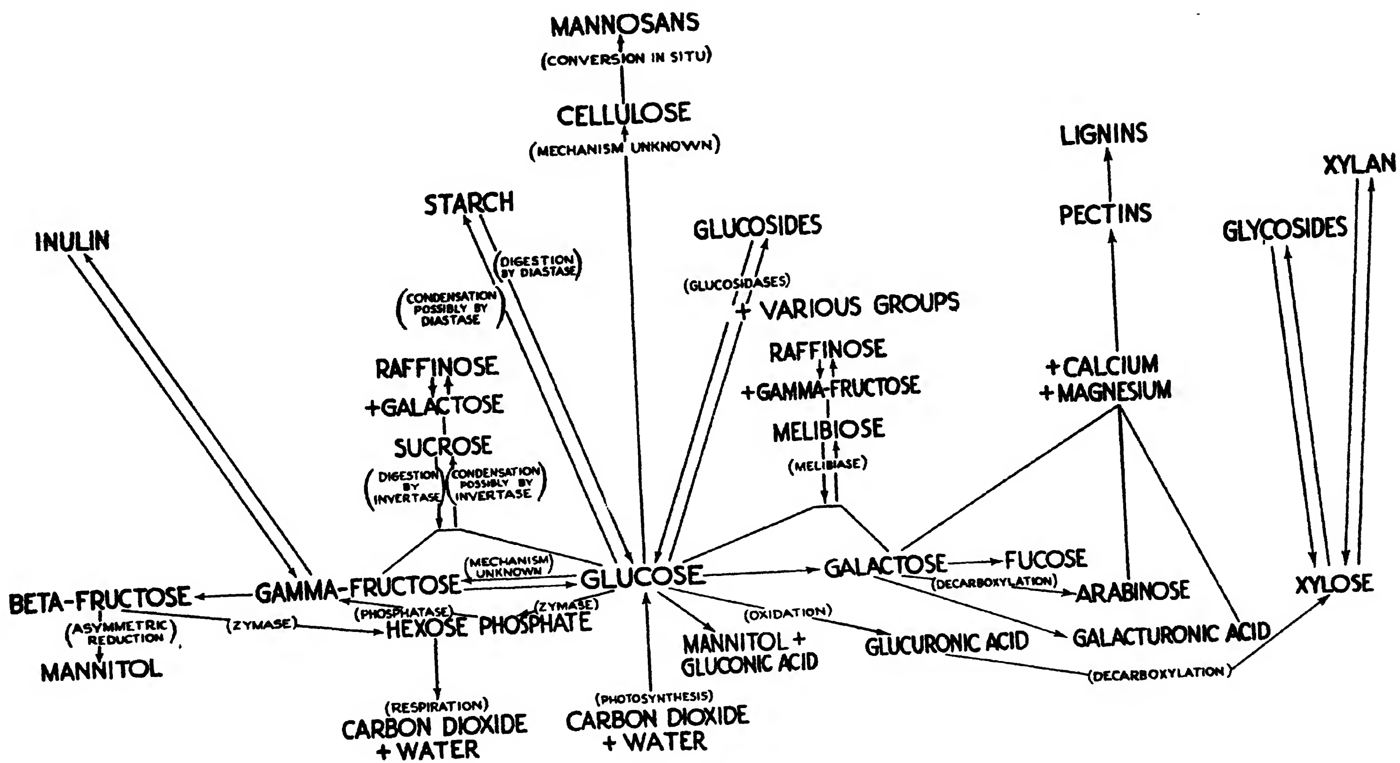


Fig. 1.

cane sugar. Starch can be converted into cane sugar. Cut leaves can make cane sugar in the dark when supplied with either glucose or fructose. Some mechanism exists in plants for the interconversion of glucose and fructose.

A diagram showing the possible relationships of the most important carbohydrate constituents in plants is presented in Fig. 1. The diagram is based on Armstrong and Armstrong (3) and other sources. Some of the changes indicated are demonstrated facts, while others are the most plausible interpretations.

B. Studies with Sugar Cane:

Inasmuch as sugar cane is one of the best sugar-producing plants in the world, it is a remarkable fact that the students investigating these important fundamental questions have seldom employed the sugar cane plant. Dr. H. A. Spoehr, the eminent authority on the subject of photosynthesis, pointed out in a lecture at the University of Hawaii (44) as well as in a private conference with the writer, that sugar cane is one of the most favorable plants for such studies and offers a unique opportunity for answering the questions raised in the introduction to this paper. Spoehr emphasized the value of conducting studies of photosynthesis in Hawaii because of the favorable climate.

One of the early studies of sugar formation in the sugar cane plant was conducted by Went (52), who was of the opinion that sucrose is the first sugar produced although as pointed out by Davis, Daish, and Sawyer (12), Went gave no evidence supporting his view. Studies both earlier and later than Went's were summarized by Viswanath (50) in 1919, who concluded that the bulk of evidence seemed to favor the view that cane sugar is built up in the stem from simple sugars sent into it by the leaf. Geerligs (20) in 1924, on the other hand, following the theory of Went, considered sucrose the first sugar. Follett-Smith (18) in 1928, sampled cane leaves at 7, 9, and 11 a. m. and 1, 3, and 5 p. m. He found that both sucrose and glucose rose during the morning and afternoon and fell in the evening, but he did not discuss the bearing of his results upon the problems of the first sugar in photosynthesis and the translocation of carbohydrates. It is unfortunate that he did not continue sampling during the night to determine the low concentrations of sugars. In another experiment (19) he collected plants at 2 p. m. for a series of days. Lower sucrose and higher glucose were found on very sunny days, while high sucrose and low glucose were found on less sunny days. This difference in sugars, however, was attributed to temperature rather than light, and explained by assuming greater inversion of sucrose on hot days.

Komatsu, Ozawa, and Makino (27) in 1933 reported a series of studies on the maturity of sugar cane. These authors are not in agreement as to what is the primary product of photosynthesis, Komatsu being of the opinion that it is a polysaccharide of the nature of starch, while Ozawa takes it for granted that a simple sugar is formed first. According to Ozawa, the most important process in the ripening of cane is the conversion of simple sugars to sucrose. Neither Komatsu nor Ozawa present experimental evidence favoring his own viewpoint. Ozawa bases an elaborate mathematical treatment of ripening upon the assumption that a simple sugar is the first product of photosynthesis.

Because of the more recent studies with other kinds of plants, most of which indicate that the simple sugars are formed first, there is need for a reconsideration of the formation of sugar in the sugar cane plant.

II. ORIGINAL RESEARCH

The writer became interested in the problems of the formation, translocation, and storage of sugar and the interrelationships between the carbohydrates in the sugar cane plant, in connection with studies of potassium deficiency in sugar cane (22, 23). Leaves of the variety H 109 when deprived of potash contained higher percentages of simple sugars, lower percentages of cane sugar, and less active invertase than the control plants which had been adequately supplied with potash. This apparent relationship between invertase and the kinds of sugars seemed best explained on the assumption that the simple sugars are formed first in photosynthesis and are later condensed to cane sugar if the invertase is sufficiently active.

Methods

In brief, the methods employed in these studies consisted in the collection of leaves at hourly or bi-hourly intervals during the day and the night, and subjecting these leaves to analysis for sugars, moisture, starch, and total polysaccharides. The leaf of the sugar cane plant consists of two distinct portions, the blade and the sheath. The blade is the flat, dark green part which is held out in the air and in which the greater part of the manufacture of food occurs. The sheath is the part which is clasped tightly around the stem; when covered entirely with other sheaths it is colorless, and when exposed to the light, it is greenish in color, but, like that of many other grasses (29), it never contains enough of the green pigment chlorophyll to carry on an important amount of photosynthesis. The most important function of the blade is the manufacture of food; the most important function of the sheath is providing a highway for the translocation of food from the blade to the stem.

In this investigation, the blades and sheaths of the same leaves were analyzed separately. The results of the studies with the blades are reported in this paper, and the data obtained from the analysis of the sheaths will be presented in a later contribution.

The Plants:

The plants were all of the variety H 109, taken from border plantings along plots at the Experiment Station. Three harvests were conducted, one in April, one in June, and one in December (1933). The plants used in April were ten months old, those in June were 12 months of age, and those in December were six months and two weeks old.

Sampling:

Counting the leaf with the highest emerged dewlap as leaf No. 1, leaves 2 and 3 (counting down) were used in all experiments. Stalks were selected the previous day and marked with white tags to facilitate sampling. Two leaves as described

above were taken each sampling hour from each of eight plants, these plants being taken at regular intervals along the entire length of the border. The blades were then rapidly separated from the sheaths, wiped, and after the removal of the midribs, were cut and then ground in a Russwin food cutter. After thorough mixing, duplicate samples for carbohydrate analyses (in December, triplicate samples) were quickly weighed and immediately plunged into boiling 95 per cent alcohol. Each sample was boiled five minutes and after the addition of another 100 cubic centimeters of boiling 95 per cent alcohol and toluene for preservation, the samples were stored in the dark until analyzed. Moisture determinations were made in the usual way. Sampling was conducted in each experiment at the hours indicated below:

April 25—p. m.	1, 3, 5, 7, 9, 11
April 26—a. m.	1, 3, 5, 6, 7, 9, 11
June 22—a. m.	4:30, 5, 5:30, 6, 6:30, 7, 7:30, 8, 9, 11
June 22—p. m.	1, 3, 5, 6, 7, 8, 9, 11
June 23—a. m.	1, 3, 4, 4:30, 5, 5:30, 6, 6:30, 7, 7:30, 8, 9
December 27—a. m.	5, 6, 7, 8, 9, 11
December 27—p. m.	1, 3, 5, 6, 7, 9, 11
December 28—a. m.	1, 3, 4, 5, 6, 7, 8, 9, 11.

Analytical Methods:

At the time of analysis the samples were extracted with hot 50 per cent alcohol, then ether, and finally 95 per cent alcohol, and were filtered. The filtrate was brought to the desired volume by the addition of 95 per cent alcohol. The sugars were then transferred from alcohol to water and concentrated on the water bath. Simple or reducing sugars (glucose and fructose) were determined by the Munson and Walker (31) method, employing the Bertrand (6) permanganate titration. Total sugars were determined by the same methods, after inversion with citric acid. Sucrose was calculated by difference. In the April experiment, the residue after extraction was used for the determination of polysaccharides, by hydrolysis with weak hydrochloric acid. In the June experiment the residue was used for the determination of starch by the Taka-diastase method of Shriner (41). Both starch and total polysaccharides were estimated in the December experiment.

Results

The April Experiment:

The results of the determinations of simple sugars, cane sugar, polysaccharides, and moisture are given in Table I, in which the first three items are expressed on the moisture-free basis. The results are graphed in Fig. 2, in which the curves have been smoothed by the method of moving averages (26). It is felt that comparisons made with graphs smoothed in this way are more reliable than the original data because this method tends to overcome the effects of individual differences and sampling errors. Solar radiation records measured by an Eppley pyreheliometer are shown in Fig. 3.

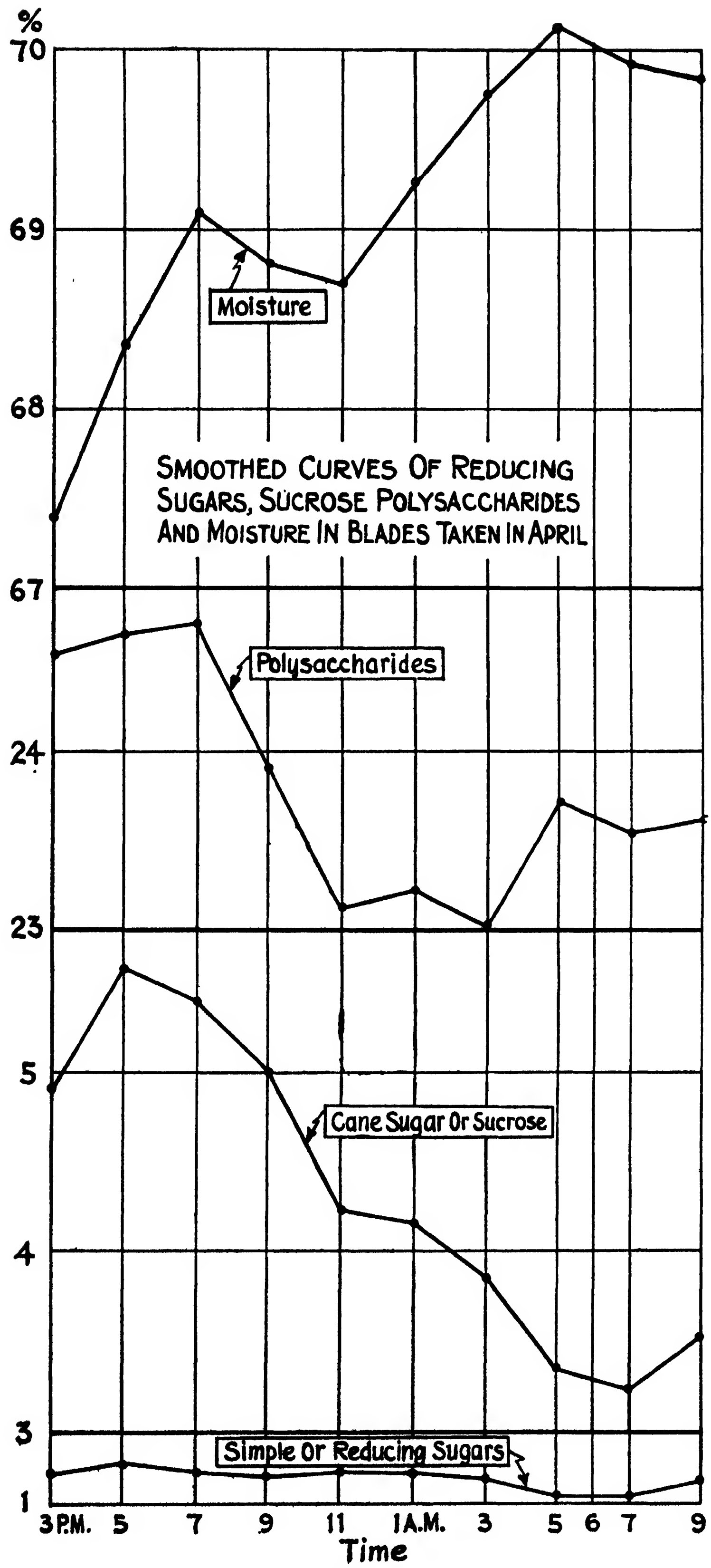

%
70
69
68
67
24
23
5
4
3
1
Moisture
SMOOTHED CURVES OF REDUCING SUGARS, SUCROSE POLYSACCHARIDES AND MOISTURE IN BLADES TAKEN IN APRIL
Polysaccharides
Cane Sugar Or Sucrose
Simple Or Reducing Sugars
3 P.M. 5 7 9 11 1 A.M. 3 5 6 7 9
Time

Fig. 2.

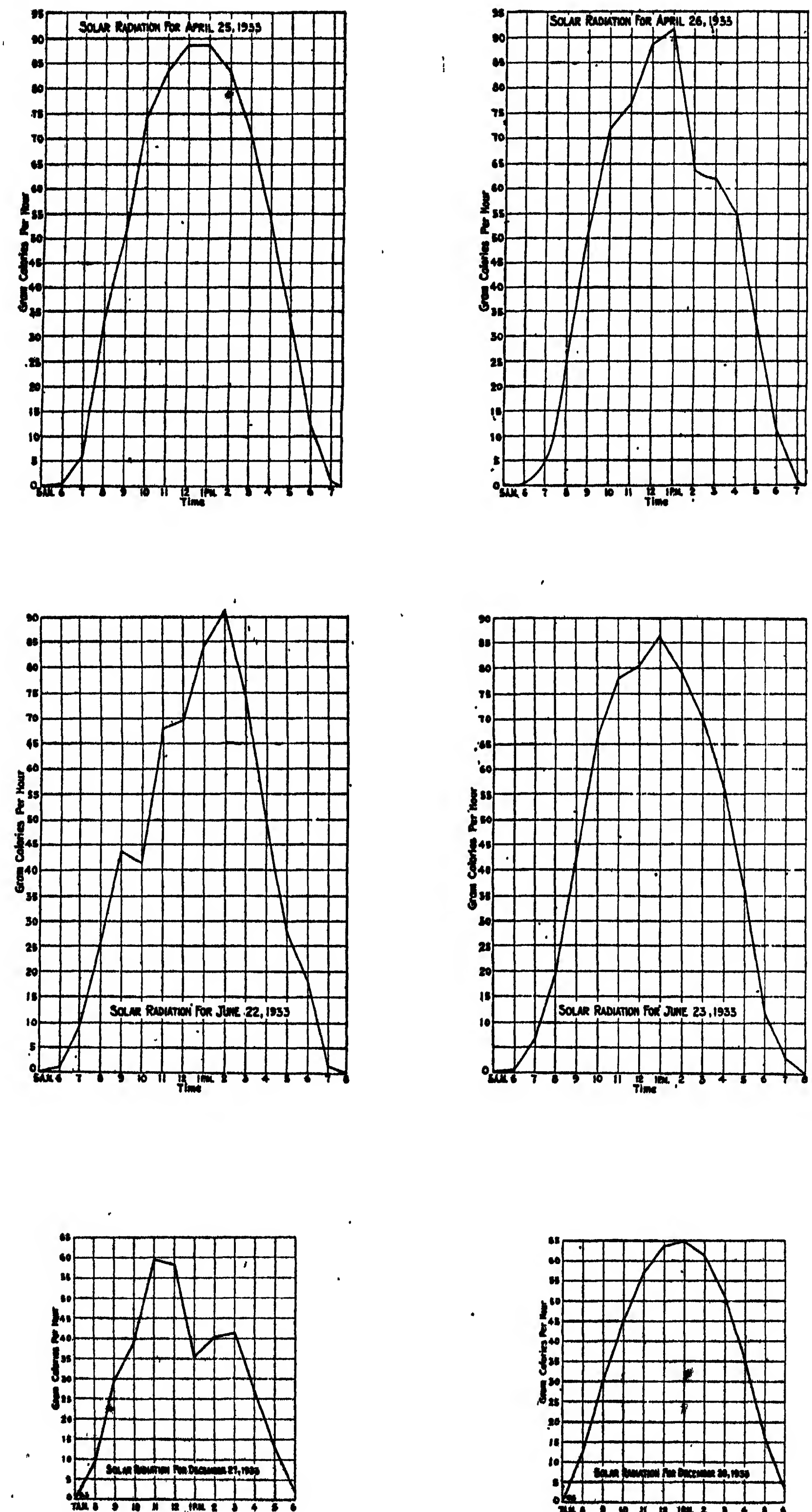

Solar Radiation For April 25, 1933
Solar Radiation For April 26, 1933
Solar Radiation For June 22, 1933
Solar Radiation For June 23, 1933
Gram Calories Per Hour
Time

Fig. 3.

TABLE I

Analyses of blades collected in April, 1933. Simple sugars, cane sugar, and polysaccharides expressed on the moisture-free basis. Also moisture percentages.

Time of Sampling	Simple Sugars	Cane Sugar	Polysaccharides	Moisture
April 25	Per Cent	Per Cent	Per Cent	Per Cent
1 p.m.	1.08±0.007	4.39±0.014	24.29±0.725	66.95±0.090
3	1.24±0.000	5.17±0.038	24.20±0.183	66.56±0.166
5	1.21±0.009	5.18±0.128	25.15±0.104	68.62±0.400
7	1.24±0.014	6,52±0.042	24.66±0.152	69.87±0.038
9	1.14±0.057	4.54±0.033	24.36±0.676	68.85±0.262
11	1.14±0.066	4.01±0.023	22.80±0.443	67.75±0.009
April 26				
1 a.m.	1.31±0.047	4.22±0.252	22.20±0.624	69.50±0.028
3	1.14±0.071	4.30±0.038	24.70±0.238	70.44±0.014
5	1.02±0.031	3.08±0.002	22.15±0.109	69.28±0.367
6	1.10±0.040	3.27±0.057	25.29±0.019	70.75±0.019
7	0.98±0.031	2.80±0.002	22.79±0.076	70.05±0.591
9	1.18±0.033	3.90±0.042	24.03±0.281	69.68±0.076
11	1.26±0.016	4.02±0.004	24.08±0.109	69.84±0.186

TABLE II

Analyses of blades collected in June. Simple sugars, cane sugar, and starch expressed on the moisture-free basis. Also moisture percentages.

Time of Sampling	Simple Sugars	Cane Sugar	Starch	Moisture
June 22	Per Cent	Per Cent	Per Cent	Per Cent
4:30 a.m.	0.864±0.009	2.295±0.033	......	67.82±0.014
5	0.845±0.007	2.440±0.061	0.246	67.69±0.109
5:30	1.140±0.016	3.110±0.038	0.308±0.004	67.55±0.038
6	0.869±0.001	2.718	0.410±0.011	67.64±0.085
6:30	1.200±0.004	2.670	0.228	67.97
7	1.070±0.007	2.650±0.007	0.259	66.55±0.019
7:30	1.120±0.026	2.820±0.021	0.086±0.009	66.74±0.047
8	1.160±0.021	3.180±0.000	0.131±0.022	67.62±0.162
9	0.979±0.014	2.581±0.048	......	66.27±0.057
11	1.010±0.020	3.462±0.096	0.190±0.001	66.16±0.076
1 p.m.	1.240±0.007	2.910±0.016	0.049±0.023	64.04±0.002
3	1.240±0.011	3.670±0.059	......	64.39±0.062
5	1.090±0.009	3.940±0.031	0.255±0.010	66.38±0.281
6	1.130±0.040	3.810±0.116	0.249±0.009	67.43±0.081
7	1.010±0.002	3.680±0.059	0.270±0.005	67.03±0.085
8	1.300±0.004	3.140±0.114	0.364±0.024	67.99±0.162
9	1.200±0.009	2.470±0.045	0.304±0.021	67.53±0.019
11	0.915±0.090	2.269±0.053	0.222±0.022	68.88±0.028
June 23				
1 a.m.	0.842±0.009	1.723±0.016	0.098±0.046	69.60±0.007
3	0.924±0.028	1.925±0.068	0.000±0.000	68.82±0.033
4	0.778±0.007	2.257±0.018	0.111±0.016	66.97±0.062
4:30	0.931	2.211±0.022	0.033±0.015	68.68±0.171
5	1.004±0.007	......	0.149±0.004	66.02±0.033
5:30	0.894±0.003	2.200±0.043	0.000±0.000	68.63±0.019
6	0.970±0.001	1.860±0.042	0.000±0.000	69.35±0.009
6:30	1.110±0.038	2.610±0.021	......	68.16±0.042
7	1.180±0.007	2.160±0.023	0.045±0.021	69.18±0.004
7:30	1.160±0.021	1.960±0.004	0.170±0.010	67.38±0.081
8	1.030±0.000	1.830±0.038	......	68.62±0.019
9	1.190±0.045	2.530±0.052	......	65.35±0.019

The June Experiment:

The results of the June experiment, calculated and expressed in the same way as the April experiment, are presented in Table II and Fig. 4, and solar radiation in Fig. 3.

The December Experiment:

Sampling was conducted in triplicate in this experiment. The results of the carbohydrate analyses were calculated on the residual dry-weight basis because that is considered more accurate than the usual moisture-free basis for experiments of short duration (15). The residual dry weight equals the dry weight from which is subtracted the sum of the total sugars plus polysaccharides. The results are given in Table III and Figs. 5 and 6, and the solar radiation in Fig. 3.

TABLE III

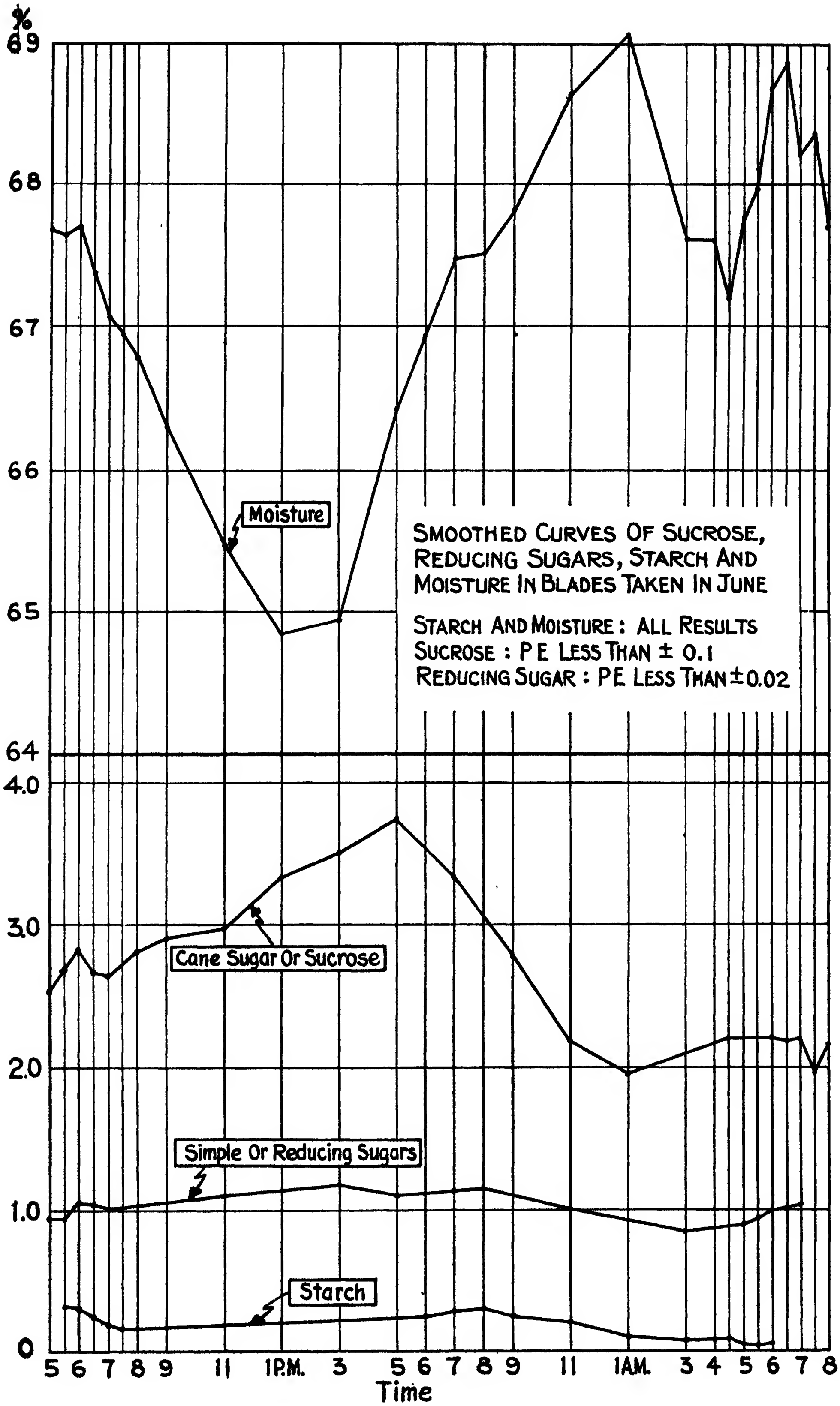
Analyses of blades collected in December. Simple sugars, cane sugar, polysaccharides, and starch expressed on residual dry-weight basis. Also moisture percentages.

Time of Sampling	Simple Sugars	Cane Sugar	Polysaccharides	Starch	Moisture
December 27	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
5 a.m.	1.211±0.006	2.706±0.144	30.91±0.472	0.867±0.110	72.85±0.038
6	1.482±0.015	1.572±0.391	25.85±0.767	0.936±0.010	74.22±0.028
7	1.550±0.038	2.881±0.172	31.98±0.290	0.708±0.014	74.22±0.314
8	1.624±0.028	2.567±0.084	31.16±0.620	0.757±0.052	72.90±0.000
9	1.787±0.022	2.479±0.059	31.07±0.946	1.547±0.097	73.57±0.066
11	1.672±0.030	3.150±0.175	31.76±1.327	1.613±0.056	71.03±0.262
1 p.m.	1.845±0.069	2.228±0.101	30.16±0.944	1.271±0.012	69.58±0.090
3	1.828±0.085	3.311±0.178	33.61±0.286	2.150±0.133	70.53±0.248
5	1.623±0.011	4.490±0.207	32.62±0.186	2.622±0.038	70.86±0.028
6	1.299±0.365	4.474±0.044	31.15±1.161	2.342±0.106	72.13±0.005
7	1.485±0.285	3.185±0.125	29.46±0.834	3.184±0.154	72.25±0.176
9	1.366±0.106	2.988±0.199	27.23±0.059	2.855±0.187	72.15
11	1.123±0.018	2.667±0.084	29.09±1.187	2.474±0.218	71.40±0.062
December 28					
1 a.m.	1.127±0.111	2.144±0.040	27.37±1.191	1.922±0.061	72.35
3	1.182±0.011	1.774±0.124	26.33±0.590	1.623±0.030	72.97
4	1.380±0.023	1.361±0.089	27.04±1.451	1.549±0.109	73.54
5	1.037±0.018	1.510±0.054	27.52±0.934	1.199±0.023	....
6	1.323±0.118	1.054±0.125	23.01±0.100	0.791±0.039	73.92±0.090
7	1.159±0.039	1.450±0.131	20.22±0.057	0.774±0.042	72.85±0.085
8	0.958±0.014	1.844±0.024	21.61±0.249	0.783±0.029	71.56±0.038
9	1.269±0.166	2.473±0.111	21.49±0.255	1.117±0.036	71.01
11	1.374±0.022	3.468±0.073	24.10±0.009	1.2[illegible]0±0.020	70.93±0.033

Discussion

Moisture:

Definite fluctuations in moisture content occurred in all three experiments. These are shown graphically in Figs. 2, 4, and 6. It is evident that the blades of sugar cane



%
69
68
67
66
65
64
4.0
3.0
2.0
1.0
0
Moisture
Smoothed Curves Of Sucrose, Reducing Sugars, Starch And Moisture In Blades Taken In June
Starch And Moisture: All Results
Sucrose: P E Less Than ± 0.1
Reducing Sugar: P.E. Less Than ± 0.02
Cane Sugar Or Sucrose
Simple Or Reducing Sugars
Starch
5 6 7 8 9 11 1P.M. 3 5 6 7 8 9 11 1AM. 3 4 5 6 7 8
Time

Fig. 4.

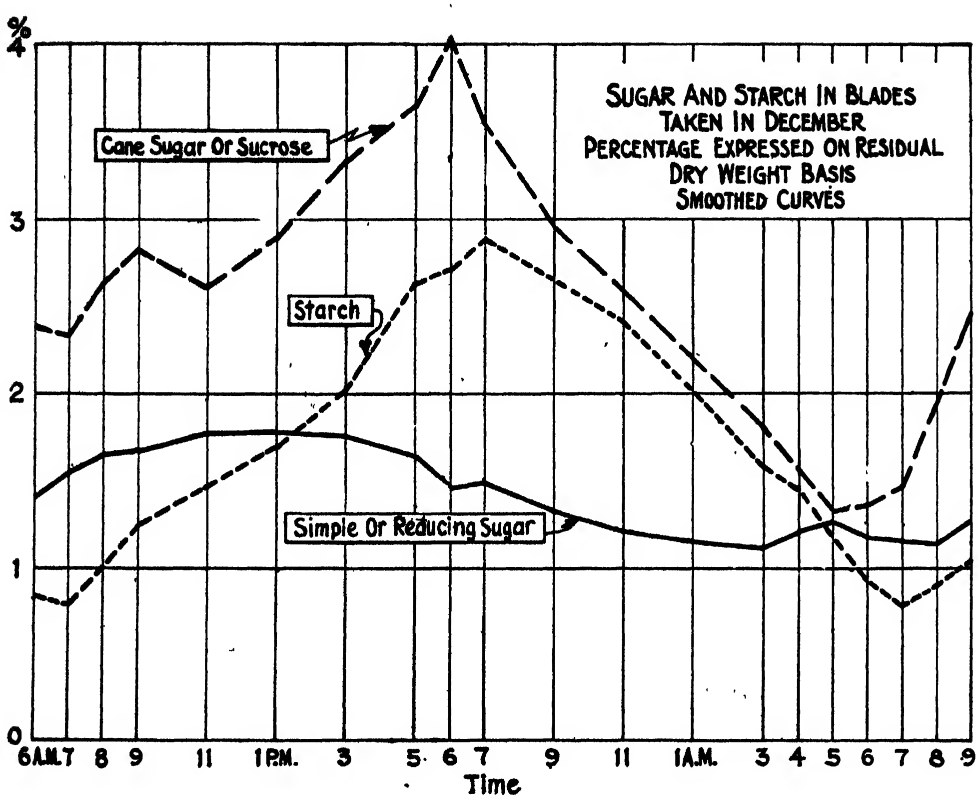

%
4
3
2
1
0
Cane Sugar Or Sucrose
Starch
Simple Or Reducing Sugar
SUGAR AND STARCH IN BLADES
TAKEN IN DECEMBER
PERCENTAGE EXPRESSED ON RESIDUAL
DRY WEIGHT BASIS
SMOOTHED CURVES
6A.M. 7 8 9 11 1P.M. 3 5 6 7 9 11 1A.M. 3 4 5 6 7 8 9
Time

Fig. 5.

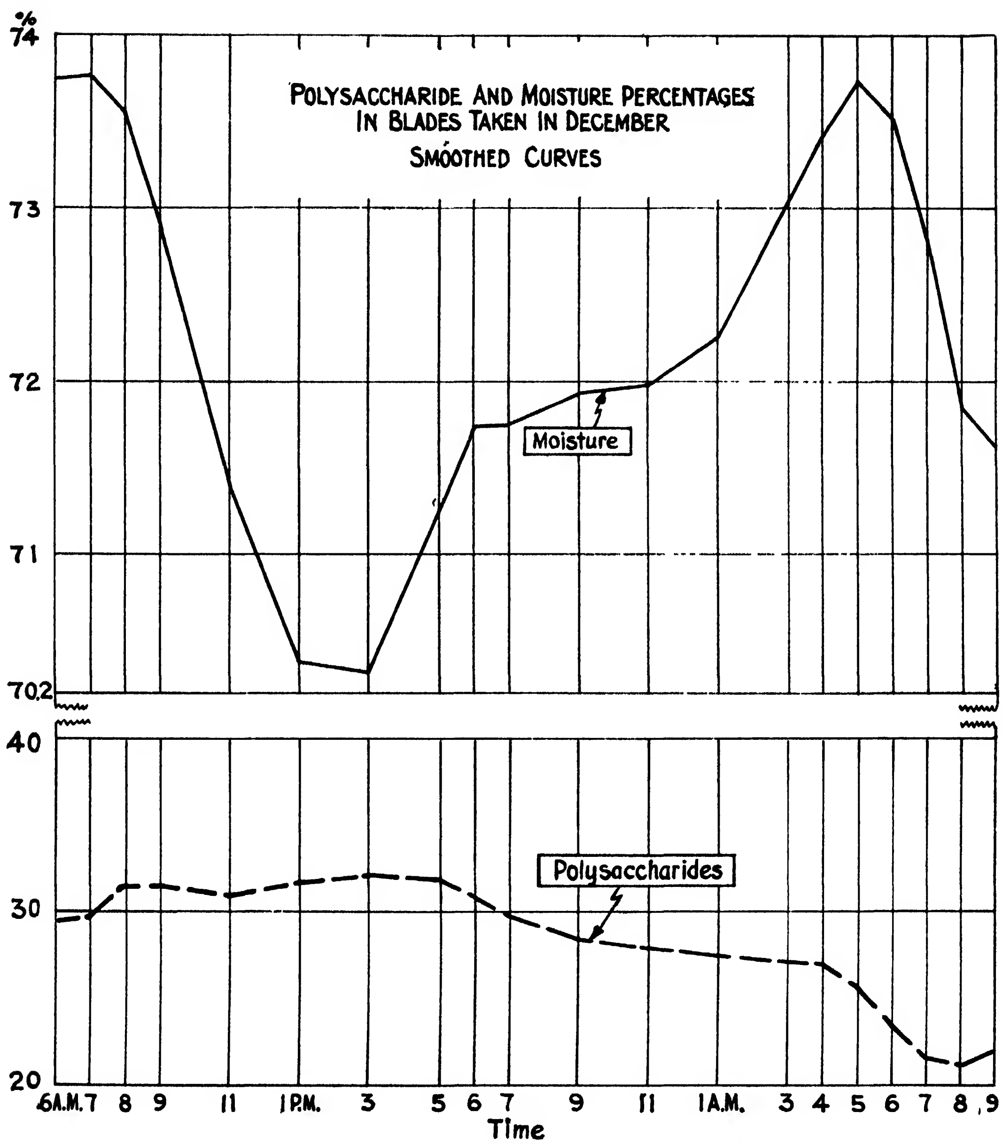

%
74
73
72
71
70.2
40
30
20
POLYSACCHARIDE AND MOISTURE PERCENTAGES
IN BLADES TAKEN IN DECEMBER
SMOOTHED CURVES
Moisture
Polysaccharides
6A.M. 7 8 9 11 1P.M. 3 5 6 7 9 11 1A.M. 3 4 5 6 7 8 9
Time

Fig. 6.

leaves contain the least water at 1 - 3 o'clock in the afternoon. This is usually the time of greatest solar radiation, with the most intense light and highest temperature. In times of drought, these are the hours of greatest danger to the leaves.

After 3 p. m., the moisture percentage increased rapidly until 6 or 7 p. m., when there was a leveling in the curve for moisture. In the April experiment an actual decrease occurred in moisture content from 7 to 11 p. m.; in June the leveling was slight and may have been due to experimental error; in December there was only a slight increase in moisture from 6 to 11 p. m., followed by a rapid rise. This cessation in the rise of the moisture percentage in the blades occurred at nightfall, thus probably at the time of stomatal closure, when one would expect an increase in moisture due to cessation of water loss through the stomatal pores. This interesting feature of the moisture content, occurring as it did in at least two of the experiments, may be a general characteristic of sugar cane leaves. Because external conditions of temperature, light and humidity, as well as stomatal closure, would lead one to expect a continuous rise in water content due to the decreasing transpiration, the decrease or leveling which actually occurred may have been due to internal causes. These moisture curves are in certain respects related to the curves for polysaccharides and as will be shown later may indicate the utilization of water in the hydrolysis of polysaccharides.

The moisture percentage of the leaves was highest in the early morning, and decreased rapidly after the coming of daylight. Therefore time of day, operating probably through light and temperature, has a profound effect upon moisture content of the blades of sugar cane.

The curves for moisture content show that the three experiments are on different levels. In the June experiment the moisture content ranged from about 65 to 69 per cent; in the April experiment from 67 to 70 per cent in round numbers, while in the December experiment the water content varied from 70 to 74 per cent. Possible explanations include variations in rainfall, in all those climatic factors generally referred to as "season," and in the age of the plant.

Rainfall during the time of the experiment does not seem to have an important effect upon the general level of water content in the blades. No rainfall at all occurred during the April and December experiments. Occasional showers occurred during the June experiment. Inasmuch as the moisture percentage was lowest in the June experiment, it would seem that some other factor is more important than rainfall in determining the water content of sugar cane leaves. Rainfall may have been responsible for the greater irregularity of the curve in the June experiment, particularly in the early morning, because it is very difficult to remove all the moisture from the surfaces of the leaves before grinding them, although every effort was made to do so.

The highest moisture percentages occurred in December, intermediate in April, and lowest in June. Although it happened that the only showers occurred in the June experiment, yet in general there is greater rainfall during December and less in June. Therefore the moisture content of the soil may have been greatest in December and that may have been the determining factor, since the importance of soil moisture in affecting the water content of plants is well known. No determinations of soil moisture were made in these experiments.

The plants used in the December experiment were six months of age, those in the April experiment 10 months old, and in the June experiment 12 months' old plants were used. Leaves from the same location on the plant were used each time in an effort to obtain comparable material, and as a result the age of the leaves differed less than the age of the plants. Whatever was the determining factor, there was an inverse relationship between the moisture content of the leaves and the age of the plant. The older the plant, the smaller the water content of the leaves.

Probably both season and age were responsible for the differences in moisture content observed in the three experiments. Which was the more important factor it is impossible to say at present.

Cane Sugar:

Striking fluctuations in sucrose content occurred during the day and the night. Cane sugar was found to increase in the blades during the day and to decrease at night. The maximum sucrose content occurred at 5 or 6 o'clock in the evening, and in each experiment this peak was followed by a rapid decrease. Thus the accumulation of cane sugar in the blades stopped with the cessation of light.

What happened in the early morning? In the April experiment sucrose decreased until 7 a. m., or until an hour after dawn. In the June experiment irregularities occurred both mornings, possibly due to rainfall; the minimum sucrose content was reached at 1 a. m.; the second morning no increase assuredly due to photosynthesis was indicated up to 8 a. m. In the December experiment sucrose reached a minimum at 7 a. m. the first day and at 5 a. m. the second day. It is interesting that sucrose did not disappear entirely from the blades at any time in any experiment. To sum up, sucrose reaches a minimum in the early morning and may begin to increase an hour before or an hour after dawn, or may show no appreciable increase even at 8 a. m. Thus some factor other than light appears to affect the time when cane sugar begins to increase in sugar cane leaves in the morning.

Among the many questions which come to mind regarding the sucrose curves, the following may be mentioned: Does the cessation of the accumulation of cane sugar at nightfall prove that sucrose is made directly in photosynthesis? Or is the fact that cane sugar does not necessarily commence to accumulate with the coming of daylight an indication that sucrose is not the primary assimilate in photosynthesis? Is the rapid decrease in cane sugar during the night caused by its inversion to glucose and fructose, or the direct translocation of cane sugar out of the blades, or by a combination of these processes? Some attempt towards a partial answer to these problems will be made after a consideration of the fluctuations of the other carbohydrate constituents in the blades.

Simple Sugars:

The simple sugars (reducing sugars) were present in much smaller amounts than cane sugar, in all three experiments. Their fluctuations during the day and the night were not as great as the fluctuations in sucrose.

Little significance could be attached to the fluctuations in simple sugars in the April experiment, considered alone, because of the relatively large experimental

error in several tests. The value of the smoothed curve for simple sugars in the April experiment is strengthened by the more evident fluctuations in June and December. Whether the greater magnitude of the fluctuations in the December experiment than in the other two experiments was due to season, to age of plant, or to more reliable results obtained from triplicate determinations, or to some other factor, we do not know. It is felt, however, that the age of the plants may have been an important factor.

In the December experiment, the maximum content of simple sugars was reached at 11 a. m., which was the time of maximum solar radiation. The simple sugars increased during the morning and decreased during the late afternoon and night. On the first morning of the December experiment, the simple or reducing sugars showed a definite increase before either starch or cane sugar had reached their minimum concentration. On the second morning in the December experiment the simple sugars increased from 3 to 5 a. m., which was before any light and therefore not due to photosynthesis. It may have been caused by the rapid hydrolysis of polysaccharides at that time. After five o'clock there was a simultaneous increase in sucrose and decrease in simple sugars, which may be evidence of condensation of simple sugars to sucrose. Sucrose began to increase at 5 a. m., starch at 7 a. m., and simple sugars at 8 a. m.

In the June experiment the relationship between the coming of light and increase in simple sugars is not clear, possibly because of rainfall. In the April experiment the simple sugars reached a minimum at 5 a. m. and began to increase after 7 a. m.

Many questions arise regarding the curves for simple sugars obtained in this investigation. Why are the simple sugars at their highest at the time of maximum solar radiation? Is their decrease during the night due to translocation, to utilization in place, or to both factors? Are their occasional increases during the night due to the hydrolysis of polysaccharides?

Starch:

Starch was not determined in the April experiment. The blades analyzed in June were very low in starch, showing a slight increase during the day and decrease at night. In the December experiment more starch was found and the fluctuations during the day and the night were considerably greater than in the June experiment.

The first day of the December experiment starch began to increase after 7 a. m. and showed a steady accumulation lasting until 7 p. m. There then followed a continuous decrease in starch until 7 a. m. the second morning and an increase from 7 to 9 a. m., the end of the experiment. The smoothed curve for starch is unencumbered by minor fluctuations, and presents a clear picture of an increase from 7 a. m. to 7 p. m., and a decrease from 7 p. m. to 7 a. m.

Only one question will be raised regarding starch. Were the higher starch content and its greater fluctuation in December than in June due to age or to season?

Polysaccharides:

Polysaccharides (or multiple sugars) include in a group such complex carbohydrates as starch, dextrine, hemicelluloses and others, and the results obtained do

not represent such a definitely known substance as starch (determined alone by the Taka-diastase method) or cane sugar or the simple sugars. Polysaccharides are considered to be reserve foods and are indirect products of photosynthesis, arising from the condensation of simple sugars. Because they are insoluble they cannot move from one place to another in a plant, but must first be digested to simple sugars before translocation can occur. This process of digestion requires water.

Polysaccharides were found to increase during the day and to decrease at night. The greatest increase occurred between 7 and 8 a.m. The most rapid decreases occurred from 5 to 7 p.m. and from 4 to 8 a.m., as shown in the December experiment. In June, polysaccharides were at a minimum during the middle of the night. The decrease in polysaccharides from 7 to 11 p.m. was accompanied by a decrease in moisture at the same time. This is only natural, inasmuch as polysaccharides can decrease only through digestion, a process which requires the utilization of water. Similarly, in the December experiment a rapid decrease in polysaccharides in the early evening was associated with a leveling in the moisture curve.

Which Sugar is Formed First in Photosynthesis?

It is impossible in the present state of our knowledge to give a decisive answer to this question. As has been explained by several authors, the greater daily fluctuations in sucrose than in the simple sugars may be used to argue either that sucrose is the first sugar or that the simple sugars are formed first, depending upon the interpretation.

It seems to the writer that the strongest evidence favoring the view that sucrose is the primary sugar is the sharp peak in the sucrose curves at nightfall, which might indicate that light is essential for the formation of cane sugar. Since it is known that light is necessary for photosynthesis, it might be argued that photosynthesis and the formation of sucrose are one and the same process, both requiring light. This does not necessarily follow. It is just as possible that light is necessary for the formation of the forerunner of sucrose, and when the supply of that forerunner is diminished, then the formation of sucrose ceases. Virtanen and Nordlund (49) found that leaves of several kinds of plants could make sucrose in the dark when supplied with either glucose or fructose. Thus it is possible that the forerunner needed for the formation of sucrose is a supply of the simple sugars, glucose and fructose, and that this supply is stopped by the lack of light. We should now ask, Is there any evidence in these experiments that the formation of sucrose depends upon the concentration of simple sugars? Is there any evidence that the concentration of simple sugars depends upon light? These two questions will now be considered.

First, Is there any evidence that the formation of cane sugar depends upon the concentration of simple sugars? Yes, there is a little such evidence in the December experiment. Sucrose decreased steadily from 6 p.m. until 5 a.m. and then increased. This increase in sucrose after 5 a.m. came immediately after an increase in simple sugars and was accompanied by a decrease in simple sugars. It may be that the decrease in sucrose was checked by the rise in simple sugars, that the increase in cane sugar which occurred before daylight was a result of the con-

densation of simple sugars, and that the formation of cane sugar was thus dependent upon the concentration of simple sugars. It may also be asked, What caused the increase in simple sugars from 3 to 5 a. m., when no photosynthesis could occur? The explanation may lie in the decrease in polysaccharides since it is known that the hydrolysis of polysaccharides leads to the formation of simple sugars.

The second question, Is there any evidence that the concentration of simple sugars depends upon light? The December experiment offers some evidence to that effect. The evidence is twofold. First, the maximum concentration of simple sugars was reached at the time of maximum solar radiation. Also, the first morning an increase in simple sugars occurred with the coming of light before sucrose began to accumulate. Neither of these points offers conclusive evidence, however, because as regards the first point, the concentration of simple sugars might have been due to temperature instead of light. The increase in simple sugars before sucrose on the first morning is also not conclusive, because it did not happen the second morning.

Now if the maximum simple sugar concentration at the time of maximum solar radiation was due to temperature rather than light, it would be due to hydrolysis, as increased temperature causes increased hydrolysis. That would mean increased hydrolysis at a time when the moisture percentage was at a minimum, which is unlikely.

There is another possible explanation for the sudden stoppage of the formation of cane sugar besides the theory that sucrose is formed directly in photosynthesis. It is possible that the action of invertase is affected by light. Evidence to this effect has recently been obtained by Murakami (32) who by the aid of filters studied the effects of single-color lights upon the action of the invertase in dried yeasts. Invertase activity was found to be stronger under red and yellow light, and weaker under green and violet light, and generally least active in the dark. The effect of light of different colors upon the activity of invertase in sugar cane has not yet been studied. If the work of Murakami can be confirmed with sugar cane and if invertase is the agent responsible for the formation of cane sugar, then it would be expected that the accumulation of sucrose would cease at nightfall. Another factor to be considered is the increasing water content, which would favor the digestion of cane sugar rather than its formation.

Thus the sharp peak in the sucrose curves at nightfall does not necessarily prove that cane sugar is the primary product of photosynthesis. The cause may lie in the cessation of the supply of a forerunner of cane sugar, in the effect of light upon the activity of invertase, the changing water content, and other factors.

If sucrose is not the first sugar in photosynthesis, then its function in the leaf is temporary storage. It must be admitted that the curve for sucrose bears a strong resemblance to the curve for starch. Starch is known to be a temporary storage product. In other words, the curve for sucrose resembles a curve for a temporary storage product. The curve for simple sugars, however, resembles a curve for a more reactive substance, with no great accumulation. Starch increased each morning at the same time sucrose increased. It may be concluded that the accumulation of sucrose and of starch are affected by the same factors. The all-important question remains, Is one of these factors the concentration of simple sugars?

Theoretically it is more plausible to consider that cane sugar is a temporary

storage product in sugar cane leaves, than to think that it is made directly in photosynthesis, for the following reason. It is well known that the piling up of end products has a retarding effect upon chemical changes, and evidence has recently been presented by Kurssanow (28) indicating that the accumulation of carbohydrates in leaves can easily lead to a lasting weakening of photosynthetic ability. Thus if cane sugar were the first product of photosynthesis its accumulation in leaves might interfere with the continuation of the photosynthetic process. If the simple sugars are formed first, their condensation to cane sugar and starch would prevent them from interfering with further photosynthesis.

Kurssanow (28) has shown that the assimilation of carbon dioxide in photosynthesis suffers a sharp depression in the middle of the day, in these plants: *Eriobotrya japonica, Pyrus Malus,* and *Cladophora* sp. This may also be true with sugar cane, inasmuch as Yap (53) found that the absorption of carbon dioxide by a cane leaf was most active from 8 to 10 a. m., decreased from 10 to 4 p. m., but was almost as active from 2 to 4 p. m. as from 8 to 10 a. m. If this were true in our December experiment, it would mean that coincident with the maximum content of simple sugars a decrease in photosynthesis occurred. This might be taken on the one hand to indicate that the maximum content of simple sugars was not caused by the maximum solar radiation if there were a decrease in photosynthesis in the middle of the day, and thus refute the suggestion made above that the concentration of simple sugars depends upon light. On the other hand it might be taken as evidence in accord with the results of Kurssanow, that the higher concentration of simple sugars has a depressing effect upon photosynthesis. The theory that the simple sugars are formed first in photosynthesis would be in agreement with the latter viewpoint and not with the former. However, all of this is highly speculative, inasmuch as no determinations of the absorption of carbon dioxide have yet been made in this research.

In conclusion, the preliminary nature of this investigation should be emphasized. The questions which arise from research of this nature are stimulating and important. The problem of the formation of sugar is being attacked from various angles, and further research will be reported as it matures. There is no doubt that the carbohydrate constituents of sugar cane blades, e.g., simple sugars, cane sugar, starch, and polysaccharides, are interrelated; that they fluctuate in concentration during the day and the night, and that a study of these fluctuations may help to elucidate some of the difficult fundamental problems of the physiology of the sugar cane plant with ultimate practical applications. Some of the questions dealing with the translocation of carbohydrates are considered in a later paper.

Acknowledgment

The writer wishes to express grateful appreciation to all those who helped in carrying on the all-night harvests. Acknowledgment of indebtedness is made particularly to Ada Forbes for her constant help in the investigation. The writer desires especially to thank Dr. H. L. Lyon for his valuable advice and encouragement during the course of the research and help in the preparation of the manuscript.

LITERATURE CITED

(1) Agee, H. P., 1932. The sugar planter looks at botany. Proceedings H.S.P.A.

(2) Ahrens, W., 1924. Weitere Untersuchungen über die Anhängigkeit des gegenseitigen Mengenverhältnisses der Kohlenhydrate im Laubblatt vom Wassergehalt. Bot. Arch. Vol. V, pp. 234-259. (Bot. Abs. 14: 1012, 1925.)

(3) Armstrong, E. F., and Armstrong, K. F., 1934. The carbohydrates. Longmans, Green and Co., New York.

(4) Barton-Wright, E. C., and Pratt, M. C., 1930. Studies in photosynthesis. II. The first sugar of carbon assimilation and the nature of the carbohydrates in the Narcissus leaf. Biochem. Jr. Vol. XXIV, pp. 1217-1234.

(5) ——————, and M'Bain, A., 1931-1932. Trans. Roy. Soc. Edin., Vol. LVII, pp. 309-349.

(6) Bertrand, G., Methods for the determination of reducing sugars. (In Hawk, P. B., Practical physiological chemistry. Fifth Ed. P. Blakiston's Son and Co., Inc., Philadelphia, 1916.)

(7) Brown, H. T. and Morris, G. H., 1893. A contribution to the chemistry and physiology of foliage leaves. Trans. Jr. Chem. Soc., Vol. LXIII, pp. 604-677.

(8) Bulgakova, Z., Giubbenet, E., and Liubimenko, V., 1930. On the mechanism of translocation of carbohydrates in the sugar beet. (Transl. title.) Physiol. Untersuch. Zuckerrübe. Erste Artikelserie. Ukrainisches Inst. Angew. Bot. Sect. Pflanzenphysiol. Charkiw. Vol. I, pp. 213-233. (Biol. Abs. Vol. VIII, p. 605, 1934.)

(9) Burkard, J., and Neuberg, C., 1934. Zur Frage nach der Entstehung des Rohrzuckers. Biochem. Ztschr. Vol. CCLXX, pp. 229-234. (Physiol. Abs. Vol. XX, p. 69, 1935.)

(10) Clements, H. F., 1930. Hourly variations in carbohydrate content of leaves and petioles. Bot. Gaz. Vol. LXXXIX, pp. 241-272.

(11) Colin, H., 1926. Les constituants du sucre de canne. La Sucrerie Belge, Vol. XLV, pp. 301-310.

(12) Davis, W. A., Daish, A. J., and Sawyer, G. C., 1915. Studies of the formation and translocation of carbohydrates in plants. I. The carbohydrates of the mangold leaf. Jr. Agr. Sci. Vol. VII, pp. 255-326.

(13) ——————, 1915. Studies of the formation and translocation of carbohydrates in plants. II. The dextrose-laevulose ratio in the mangold. Jr. Agr. Sci., Vol. VII, pp. 327-351.

(14) ——————, and Sawyer, G. C., 1915. Studies of the formation and translocation of carbohydrates in plants. III. The carbohydrates of the leaf and leaf stalks of the potato. The mechanism of the degredation of starch in the leaf. Jr. Agr. Sci. Vol. VII, pp. 352-384.

(15) Denny, F. E., 1932. Changes in leaves during the night. Contrib. Boyce Thompson Inst. Vol. IV, pp. 65-84.

(16) De Vries, H., 1878. Neue Ztschr. f. Rücenzuckerind. (Cited by Colin, M. H., Le saccharose dans la betterave. Formation et disparition. Rev. Gén. Bot., Vol. XXVIII, pp. 321-328, 1916.)

(17) Dixon, H. H., and Mason, T. G., 1916. The primary sugar of photosynthesis. Nature, Vol. XCVII, p. 160.

(18) Follett-Smith, R. R., 1928. The effect of some growth conditions on chemical composition and metabolism in the sugar-cane leaf. Minutes and Proc. of Froghopper Invest. Com., Part X, pp. 331-347, Trinidad Gov. Print. Of., Port-of-Spain.

(19) ——————, 1928. Variation in chemical composition of the sugar-cane leaf due to different conditions of insolation. Minutes and Proc. of Froghopper Invest. Com., Part XIII, pp. 165-173.

(20) Geerligs, H. C. P., 1924. Cane sugar and its manufacture. Second Rev. Ed., Norman Rodger, London.

(21) Gortner, R. A., 1929. Outlines of biochemistry. John Wiley and Sons, Inc., New York.

(22) Hartt, C. E., 1933. Studies of the invertase of sugar cane. A preliminary report. The Hawaiian Planters' Record, Vol. XXXVII, pp. 13-14.

(23) —————, 1934. Some effects of potassium upon the amounts of protein and amino forms of nitrogen, sugars, and enzyme activity of sugar cane. Plant Physiol. Vol. IX, pp. 453-490.

(24) —————, 1934. Water and cane ripening. The Hawaiian Planters' Record, Vol. XXXVIII, pp. 193-206.

(25) Hasselbring, H., 1932. Effect of hot-water treatment on the carbohydrate changes in Narcissus bulbs during storage. Plant Physiol. Vol. VII, pp. 145-154.

(26) Jerome, H., 1924. Statistical method. Harper and Bros., New York.

(27) Komatsu, S., Ozawa, S., and Makino, Y., 1933. Biochemical studies on the "maturity" of sugar cane. Mem. Col. Sci. Kyoto Imp. Univ. Series A16, pp. 1-125.

(28) Kurssanow, A. L., 1933. Ueber den Einfluss der Kohlenhydrate auf den Tagesverlauf der Photosynthese. Planta Vol. XX, pp. 535-548.

(29) Liubimenko, V. N., 1928. The part played by the leaf sheaths of graminaceous plants in the gas exchange in photosynthesis and in the accumulation of dry matter. (Transl. title.) Sbornik Sortovodno-Semennogo Upravleniia Sakharotresta. Kiev. Vol. VI, pp. 122-124. (Biol. Abs. Vol. VIII, p. 602, 1934.)

(30) —————, and Rubinov, K. M., 1929. Transformation of soluble carbohydrates in the roots of Taraxacum officinale in different stages of its development. (Transl. title.) Bull. Jardin Bot. Prin., USSR Vol. XXVIII, pp. 357-367. (Biol. Abs. Vol. VIII, p. 2171, 1934.)

(31) Munson, L. S., and Walker, P. H., 1906. The unification of reducing sugar methods. Jr. Am. Chem. Soc. Vol. XXVIII, pp. 663-686.

(32) Murakami, R., 1934. The influence of monochromatic lights on the action of invertase in dried yeasts. (Trans. title.) Bull. Utsunomiya Agric. Coll. Vol. V, pp. 29-36. (Biol. Abs. Vol. IX, p. 1016, 1935.)

(33) Nordlund, M., 1935. Studies on the carbohydrate metabolism of the plant. Suomen Kemistilehti B. No. 1 (1 page).

(34) Oparin, A., and Kurssanow, A., 1931. Ueber die enzymatische Synthese des Rohrzuckers. Biochem. Ztschr. Vol. CCXXXIX, pp. 1-17.

(35) Parkin, J., 1912. The carbohydrates of the foliage leaf of the snowdrop (Galanthus nivalis, L.) and their bearing on the first sugar of photosynthesis. Biochem. Jr. Vol. VI, pp. 1-47.

(36) Priestley, J. H., 1924. The first sugar of photosynthesis and the rôle of cane sugar in the plant. New Phytol. Vol. XXIII, pp. 255-265.

(37) —————, 1931. The first sugar of photosynthesis and the rôle of cane sugar in the plant. Nature, Vol. CXXVII, pp. 634-635.

(38) Pringsheim, H., 1932. The chemistry of the monosaccharides and of the polysaccharides. McGraw-Hill Book Co., Inc., New York.

(39) Sachs, J., 1862. Ueber den Einfluss des Lichtes auf die Bildung des Amylums in den Chlorophyllkörnern. Bot. Zeit. Vol. XX, pp. 365-373.

(40) —————, 1964. Ueber die Auflösung und Wiederbildung des Amylums in den Chlorophyllkörnern bei wechselnder Beleuchtung. Bot. Zeit. Vol. XXII, pp. 289-294.

(41) Shriner, R., 1932. Determination of starch in plant tissues. Plant Physiol. Vol. VII, pp. 541-546.

(42) Schroeder, H., and Herrmann, F., 1931. Ueber die Kohlenhydrate und den Kohlenhydratestoffwechsel der Laubblätter. I. Die Zunahme des Saccharosegehaltes beim Welken. Biochem. Ztschr. Vol. CCXXXV, pp. 407-424.

(43) Spoehr, H. A., 1926. Photosynthesis. The Chemical Catalog Company, New York.

(44) —————, 1935. Lecture on photosynthesis. (January 30) Grad. Sch. of Trop. Agr., Univ. of Hawaii.

(45) —————, 1935. Personal Communication.

(46) Steele, C. C., 1934. An introduction to plant biochemistry. G. Bell and Sons, Ltd., London.

(47) Stiles, W., 1925. Photosynthesis, the assimilation of carbon by green plants. Longmans, Green and Co., London.

(48) Tottingham, W. E., Lepkovsky, S., Schulz, E. R., and Link, K. P., 1926. Climatic effects in the metabolism of the sugar beet. Jr. Agr. Res. Vol. XXXIII, pp. 59-76.

(49) Virtanen, A. I., and Nordlund, M., 1934. Synthesis of sucrose in plant tissue. Biochem. Jr. Vol. XXVIII, pp. 1729-1732.

(50) Viswanath, B., 1929. Studies in the chemistry of sugar cane. Agr. Jr. India, Vol. XIV, pp. 440-475.

(51) Weevers, T., 1924. The first carbohydrates that originate during the assimilatory process. A physiological study with variegated leaves. Kon. Akad. Wetensch. Amsterdam, Proc. (Eng. Version), Vol. XXVII, pp. 1-11. (Cited by Stiles, W., Photosynthesis, the assimilation of carbon by green plants. Longmans, Green and Co., London, 1925.)

(52) Went, F. A. F. C., 1897-1898. Recherches sur la physiologie chimique de la canne à sucre. Bull. de l'Assn. Chem. Vol. XV, pp. 807-812, 935-936, 1217-1226.

(53) Yap, G. G., 1920. A study of the photosynthesis of sugar cane. Philippine Agri. Vol. VIII, pp. 269-276.

The Effect of Lime Applications on Juice Quality*

By R. E. Doty

A number of lime experiments harvested along the Hilo Coast have given results showing a slight increase in cane yield from applications of lime, but such increase has been accompanied by a corresponding decrease in the quality ratio, and an actual loss in sugar.

The present test was undertaken to study, in somewhat more detail than previous tests, the effect of lime on juice quality. The site selected was a field at the Manoa substation that had an acid soil with a pH of 4.9. Lime applications at the rate of 3,700 and 10,700 pounds ($CaCO_3$) ground limestone per acre were calculated to raise this original soil pH to 6.5 and 7.8 respectively. There were twenty plots, each containing 400 square feet or .0092 acre.

The plan of fertilization follows:

1934 Crop — Fertilization—Pounds per Acre

Plots	No. of Plots	Lime ($CaCO_3$ ground before planting)	July 6, 1933: A.S. 50 lbs. N	July 6, 1933: Treble Super 500 lbs. P_2O_5	July 6, 1933: Mur. Pot. 125 lbs. K_2O	Oct. 18, '33 Pot. Nit. 125 lbs. K_2O 36.9 lbs. N	Jan. 12, '34 Pot. Nit. 169.2 lbs. K_2O 50 lbs. N	Mar. 23, '34 A.S. N.S. 60 lbs. N	Totals: N	Totals: P_2O_5	Totals: K_2O
All	20		243.9	1243.8	204.6	284.1	384.6	193.5 lbs. NS 146.3 lbs. AS	196.9	500	419
A	7	0									
B	7	3,700									
C	6	10,700									

N.S.=15.5% N
A.S.=20.5% N
Pot. Nit.=13% N, 44% K_2O
Mur. Pot.=61.1% K_2O
Treble Super=40.2% P_2O_5

* This study conducted under Project A-105, No. 29, Part I.

Procedure

The lime treatments were applied and mixed well into the soil on June 16, 1933. On July 6, 1933, the POJ 36 cane was planted and at this time the first application of fertilizer was made with the seed in shallow furrows. The remaining fertilization was carried out as indicated.

Determinations of soil pH were made for each plot before any treatment was applied and these were repeated on October 16, 1933, and again on November 2, 1934, in order to note the changes that might be occurring in the field.

The cane was harvested in three lots at ages of 16, 18 and 20 months. Samples of sound cane only were milled and juice therefrom analyzed for Brix, polarization, and glucose.

Discussion

Soil Reaction:

The original pH of the soil in these plots averaged 4.9 and the pH values desired after the application of lime, for the treatments "B" and "C," were pH 6.5 and pH 7.8 respectively. The status of the pH in the individual plots while the crop was growing is shown in Columns 4 and 5 of Table 1. The first soil samples taken four months after the applications of lime showed little deviation from the desired pH for the three series. However, more than a year later (November 2, 1934) the "A" series with its unlimed natural soil showed somewhat less acidity than originally, the "B" series had registered practically no change, while the "C" series which had been heavily limed to establish a pH of 7.8 had lost much of its alkalinity, and was but little different from the "B" series.

Weights and Analyses:

The first harvest was on November 2, 1934, when the cane was 16 months old; the second on January 3, 1935, at the age of 18 months, and the third and final harvest on March 2, when the cane was 20 months old. At each harvest the juice analysis for each plot included Brix and polarization, from which purity and quality ratio were calculated, and also glucose determinations. Comparable cane weights were secured.

Harvesting Results

The detailed data of Tables* 2, 3 and 4 are summarized in Table 2 and Figs. 1, 2, 3 and 4.

For the first harvest we note a significant loss in cane weights, a distinctly poorer purity and quality ratio, and an increased glucose content of the heavily limed "C" plots.

In the second harvest the cane weights are not significantly different but the purity and quality ratio for the heavily limed plots have been even more severely affected than in the first harvest. The effect on glucose at this harvest is not significant.

*** These tables are not published here but are on file at the Experiment Station, H.S.P.A., under Project A-105, No. 29.**

The third harvest shows no differences in cane yields, but the lower purity, poorer quality ratio, and increased glucose are still apparent from the plots that received the heavier applications of lime.

By this time, heavy rat damage interfered with the accuracy of the cane weights.

Observations:

The growth of the cane in the field showed marked differences at an early age. Notes made at 3 and 7 months of age showed that the high-limed ("C") plots were visibly inferior in growth to the unlimed plots.

Summary:

Supporting previous experience, the test reported here has shown definitely poorer purities and quality ratios of cane grown when lime was applied to acid soils before planting. In addition, it would appear that glucose is quite likely to be higher in the cane grown in these limed soils. The reasons for such results have not been ascertained.

TABLE 1

DETERMINATIONS OF pH BEFORE AND AFTER TREATMENT

Lime added on June 16, 1933, to bring A plots to pH 5.0;
B plots to pH 6.5 and C plots to pH 7.8.

Treatment	Plot Nos.	Original pH Dec. 29, 1932 before treatment	pH Oct. 16, 1933 4 months after treatment	pH Nov. 2, 1934
(1)	(2)	(3)	(4)	(5)
A	1	4.9	4.9	6.2
	4	4.9	4.8	5.8
	7	5.0	4.5	5.9
(no lime)	10	4.9	5.3	5.7
	13	4.9	4.6	5.8
	16	4.9	4.5	6.0
	19	4.6	4.8	5.9
Average		4.87	4.77	5.87
B	2	5.2	6.1	6.5
	5	5.2	7.3	6.7
	8	5.0	6.3	6.5
(3,700 lbs. lime)	11	5.0	6.4	6.4
	14	4.9	6.1	6.5
	17	5.0	6.3	6.5
	20	4.6	6.5	6.6
Average		4.98	6.43	6.52
C	3	5.2	7.5	6.8
	6	4.6	7.8	6.8
(10,700 lbs. lime)	9	4.9	7.2	6.6
	12	4.9	7.4	6.7
	15	4.6	7.6	6.8
	18	4.9	7.0	6.7
Average		4.85	7.4	6.73

TABLE 2*

SUMMARY OF YIELDS

Project A-105, No. 29—Part I

Plots	No. of Plots	Treatment	Gross Cane Weights	Purity	Q.R.	Glucose
		First Harvest—Age 16 Months				
A	7	pH 5.0—no lime	92.0±1.9	86.44±.23	9.31±.12	0.72±.02
B	7	pH 6.5—3,700 lbs. lime per acre	88.8±0.9	85.42±.59	9.64±.21	0.80±.06
C	6	pH 7.8—10,700 lbs. lime per acre	84.5±2.6	83.70±.52	10.26±.21	0.89±.06
		Second Harvest—Age 18 Months				
A	7	pH 5.0—no lime	72.8±2.4	88.52±.54	8.89±.16	0.57±.03
B	7	pH 6.5—3,700 lbs. lime per acre	70.9±1.5	86.66±.64	9.66±.19	0.58±.04
C	6	pH 7.8—10,700 lbs. lime per acre	70.4±2.3	84.75±.95	10.47±.23	0.52±.03
		Third Harvest—Age 20 Months				
A	7	pH 5.0—no lime	60.6±2.5	89.40±.48	8.69±.17	0.36±.02
B	7	pH 6.5—3,700 lbs. lime per acre	62.8±1.7	88.65±.43	8.96±.16	0.39±.02
C	6	pH 7.8—10,700 lbs. lime per acre	59.8±1.6	86.97±.57	9.65±.16	0.51±.04

SUMMARY OF DIFFERENCES (Student's Method)

Comparing Gain of	No. of Pairs	Purity	Signif. Odds	Q. R.**	Signif. Odds
First Harvest—Age 16 Months					
A (pH 5.0) over B (pH 6.5)	6	+1.29	Low	+ .34	Low
B (pH 6.5) over C (pH 7.8)	6	+1.65	Low	+ .62	Low
A (pH 5.0) over C (pH 7.8)	6	+2.82	High	+ .96	High
Second Harvest—Age 18 Months					
A (pH 5.0) over B (pH 6.5)	6	+2.50	Doubtful	+ .77	Favorable
B (pH 6.5) over C (pH 7.8)	6	+2.00	Low	+ .81	Doubtful
A (pH 5.0) over C (pH 7.8)	6	+4.54	Very high	+1.58	Very high
Third Harvest—Age 20 Months					
A (pH 5.0) over B (pH 6.5)	6	+ .66	Low	+ .27	Low
B (pH 6.5) over C (pH 7.8)	6	+1.63	Doubtful	+ .69	Favorable to high
A (pH 5.0) over C (pH 7.8)	6	+2.65	Favorable	+ .96	High

* Compiled from Tables 2, 3, and 4 which may be consulted in Project File, H.S.P.A. Experiment Station Library, under A-105, No. 29.

**A + sign indicates a better quality ratio (lower figure) favoring the first treatment.

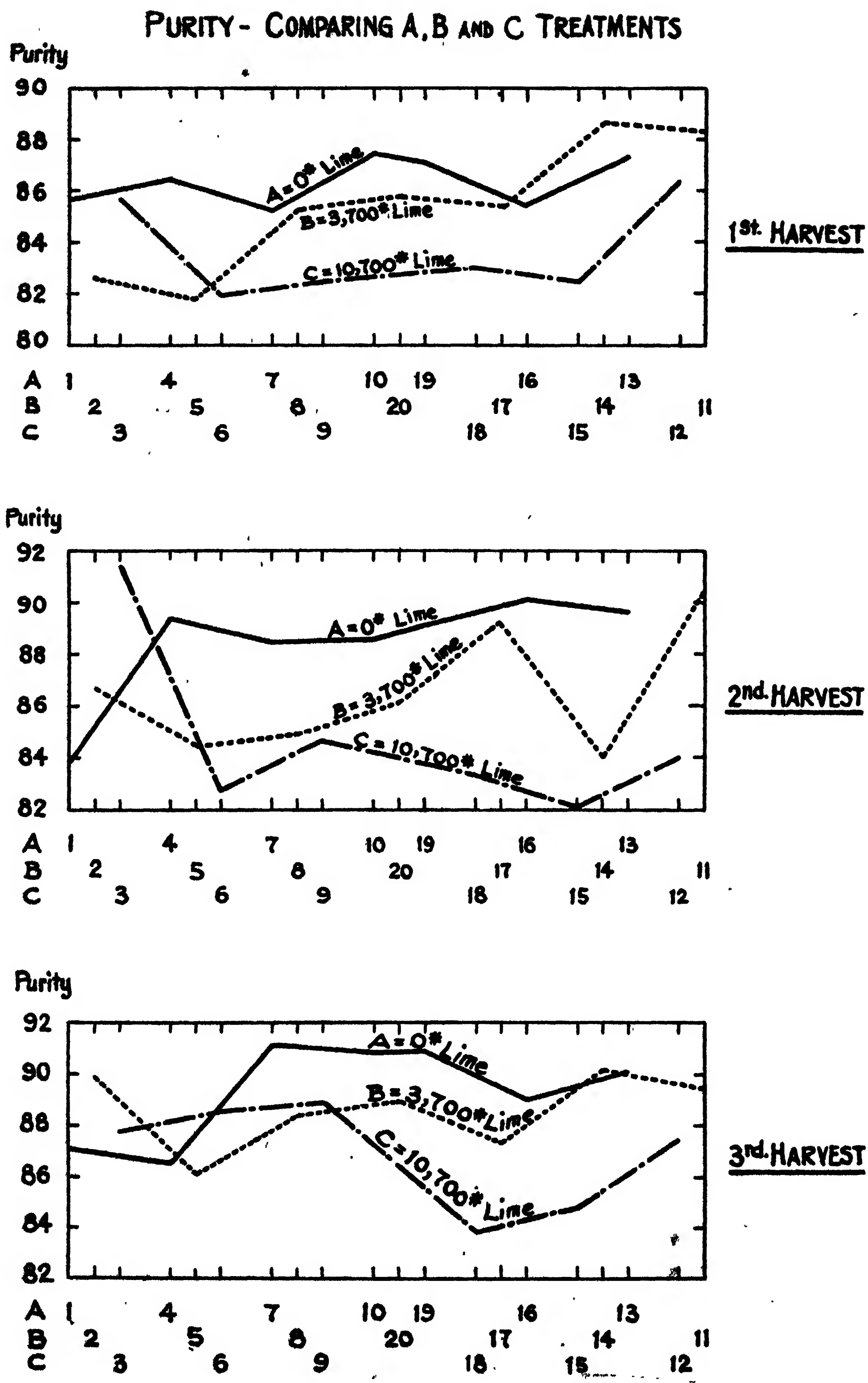

PURITY - COMPARING A, B AND C TREATMENTS
Purity
90
88
86
84
82
80
A=0# Lime
B=3,700# Lime
C=10,700# Lime
1st. HARVEST
A 1 4 7 10 19 16 13
B 2 5 8 20 17 14 11
C 3 6 9 18 15 12
Purity
92
90
88
86
84
82
A=0# Lime
B=3,700# Lime
C=10,700# Lime
2nd. HARVEST
A 1 4 7 10 19 16 13
B 2 5 8 20 17 14 11
C 3 6 9 18 15 12
Purity
92
90
88
86
84
82
A=0# Lime
B=3,700# Lime
C=10,700# Lime
3rd. HARVEST
A 1 4 7 10 19 16 13
B 2 5 8 20 17 14 11
C 3 6 9 18 15 12

Fig. 1.

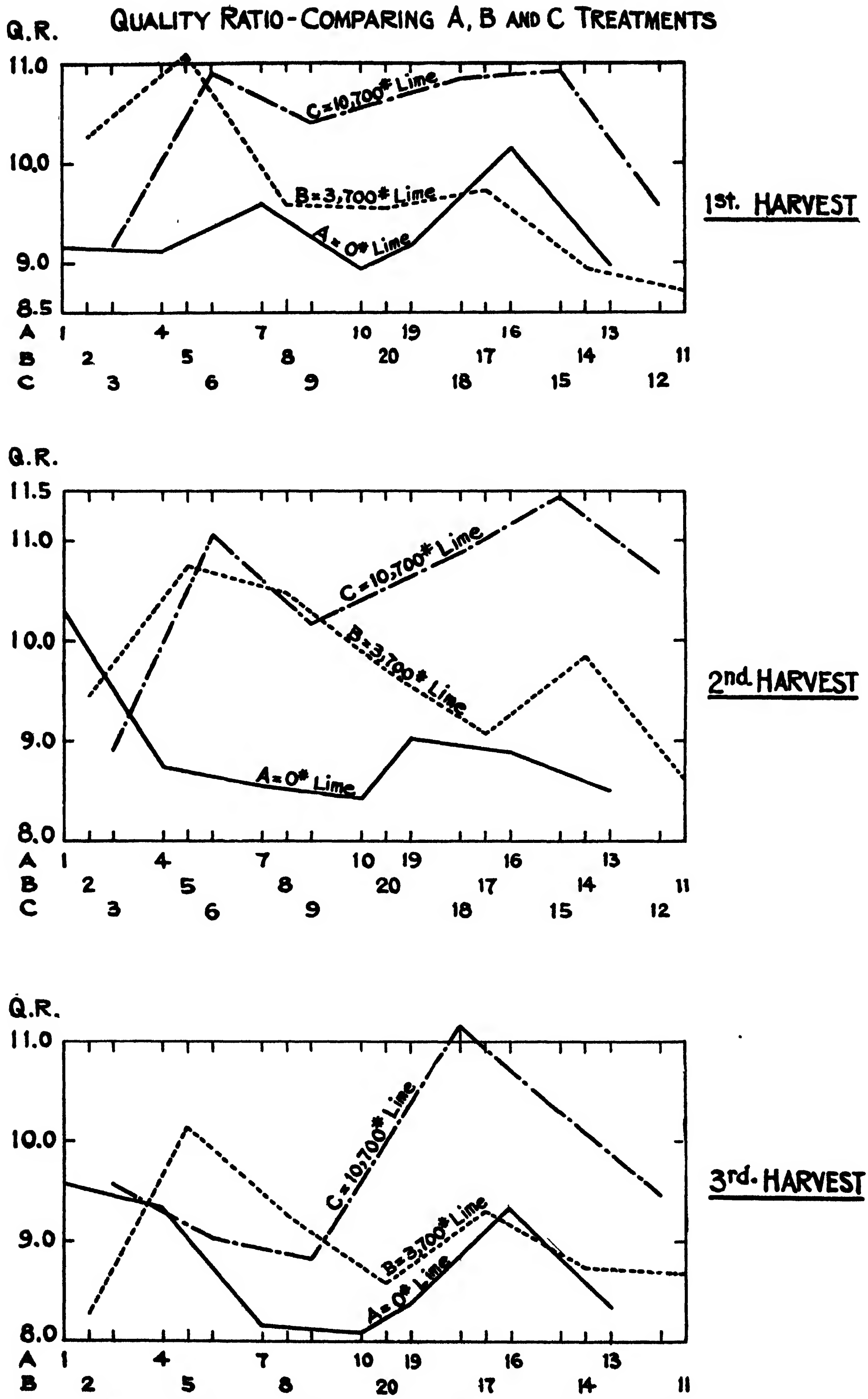
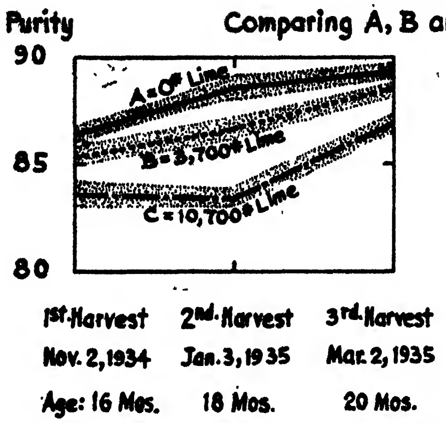

QUALITY RATIO-COMPARING A, B AND C TREATMENTS
Q.R.
C=10,700# Lime
B=3,700# Lime
A=0# Lime
1st. HARVEST
2nd. HARVEST
3rd. HARVEST
A 1 4 7 10 19 16 13
B 2 5 8 20 17 14 11
C 3 6 9 18 15 12

Fig. 2.

Average Purity
3 Harvests
Comparing A, B and C treatments



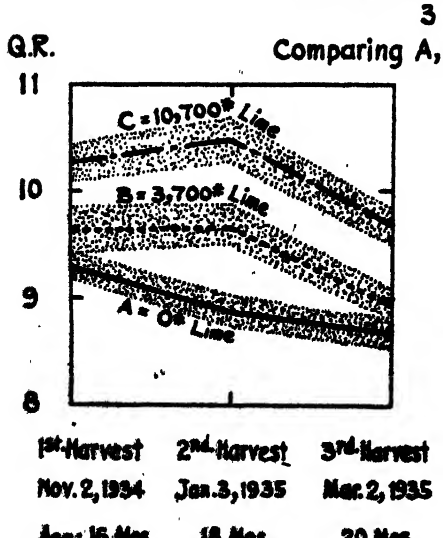
Plots	1st. Harvest	2nd. Harvest	3rd. Harvest
A	86.44±.24	*89.29±.18 88.52±.54	89.40±.34
B	85.42±.59	86.66±.64	88.65±.28
C	83.70±.52	@83.38±.31 84.75±.95	86.96±.35

* = Omitting plot 1A
@ = Omitting plot 3C

Note:- Shaded portion represents probable error zone.

Fig. 3.

Average Quality Ratios
3 Harvests
Comparing A, B and C treatments



Plots	1st. Harvest	2nd. Harvest	3rd. Harvest
A	9.31±.12	8.89±.16	8.69±.17
B	9.64±.21	9.66±.19	8.96±.16
C	10.26±.21	10.47±.23	9.65±.16

Note:- Shaded portion represents probable error zone.

Fig. 4.

Ceresan Treatment of Seed Cane

By R. E. Doty

Ceresan has proven to be a great aid in securing good germination of seed cane during wet and cold weather. It is now regular practice to dip in 1 per cent Ceresan all seed which is to be planted at Kailua substation during the winter months.

The extensive work (167 tests) of R. Urata, under Dr. A. J. Mangelsdorf's direction in 1931-32 on the prevention and control of rot in sugar cane seed pieces, tested out a large number of chemicals that might offer a control. In this work there is a preponderance of evidence that Ceresan dipped seed germinates much better than untreated seed, with less seed piece rot under unfavorable conditions such as are found during the cold wet months at Kailua substation. Germinations were increased ranging from 20 to 50 per cent, with a good average around 35 per cent. H 109 showed increased germination but a slightly decreased average length of shoots. Urata (1) states: "The varieties Yellow Caledonia, POJ 2878 and POJ 36 did not show such ill effect."

The test here reported was started with H 109 seed not only to check the increase in germination due to dipping the seed in a 1 per cent solution of Ceresan but mainly to determine if there was stimulation of the young shoots after they had germinated. The test was conducted for a period of 71 days from April 9 to June 20, 1935. Unfortunately a period of bad weather in January and February prevented the plowing and preparing of the land for this test at the time scheduled. After April 1 the ground was only moderately wet and cold as compared with what it would have been from January to March. Therefore, the benefit accruing from Ceresan was greatly minimized in the present test.

Germination

The germination counts are given in the following summary:

GERMINATION COUNTS—H 109 SEED

Treatment	Number of Rows	Number of Eyes Planted	Number of Shoots Final Germination Count 71 Days After Planting	Final Per Cent Germination	Signif. by Student's Method
Ceresan	5	1104	517	49.0	
Check	5	1145	457	41.05	
			Gain for Ceresan......	8.0	Favorable

The following chart shows the per cent germination of the primary shoots only

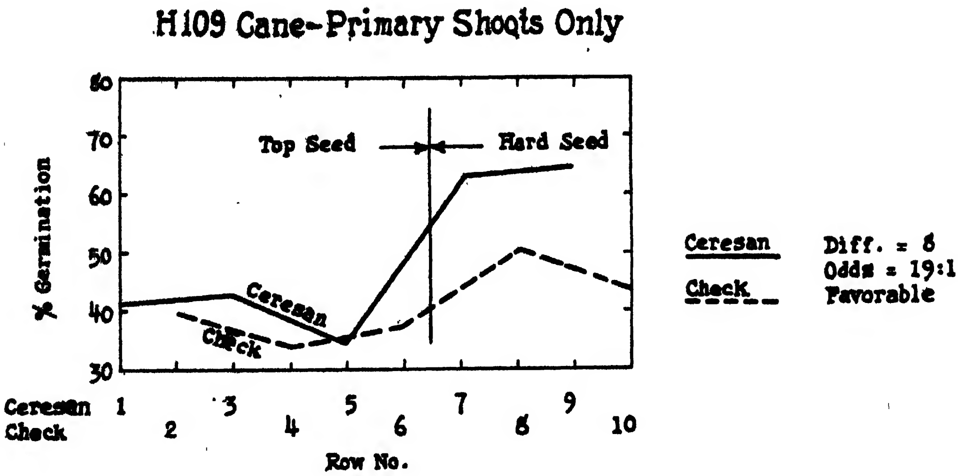


Fig. 1.

The summary of germination counts shows that the average germination percentage was increased by 8 per cent due to Ceresan treatment, with favorable significance.

A study of the graph shows that most of this benefit accrued to the hard-eyed seed, leaving very little increase to top seed. Had there been very wet weather after planting, the increased percentage favoring Ceresan would have been much larger. This has been the experience at Kailua during the winter months.

Growth of Primary Shoots

All shoots in the test were measured to the highest visible dewlap and recorded. The following table gives the results in detail:

LENGTH OF PRIMARY SHOOTS—71 DAYS AFTER PLANTING

Treatment to H 109 Seed	Number of Shoots	Total Length of Primary Shoots—Inches	Average Length of Primary Shoots—Inches	Signif. by Student's Method
Ceresan	517	3789.0	7.66	
Check	457	3791.5	8.28	
		Average loss for Ceresan....	.6	Low

The following chart was prepared from the detailed data.

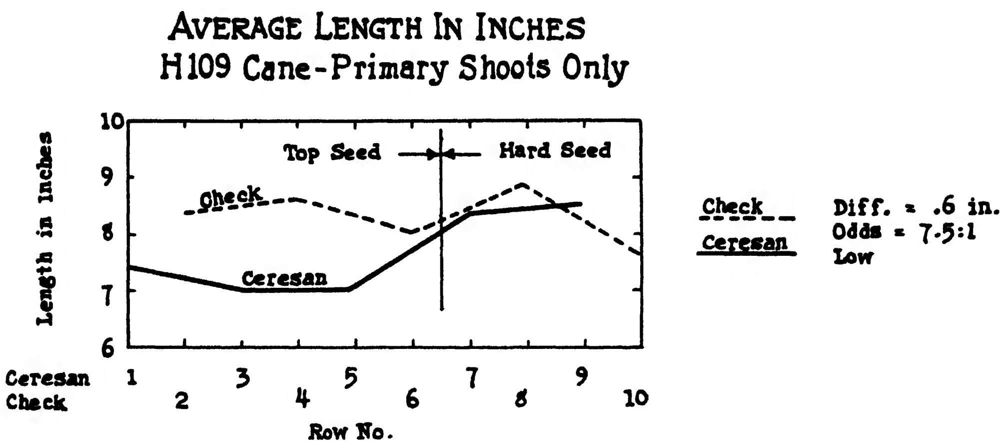


Fig. 2.

From the result it appears that the shoots of H 109 were not stimulated but rather depressed by the Ceresan treatment, there being .6 inch less growth on the Ceresan rows than in the check. Most of the depression resulting from Ceresan showed on the top seed with very little effect being evident in the hard seed. The number of row replications is too few to give significance.

This agrees with the reports of Mr. Urata on the behavior of H 109 seed mentioned earlier in this discussion.

LITERATURE CITED

(1) Urata, R., 1932. Letter of March 7, to J. A. Verret, Agriculturist. Project File No. 446, Expt. Sta., H.S.P.A. (Unpublished).

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
JUNE 19, 1935, TO SEPTEMBER 6, 1935.

	Date	Per Pound	Per Ton	Remarks
June	19, 1935........	3.28¢	$65.60	Cubas.
"	24.............	3.295	65.90	Cubas, 3.29; Puerto Ricos, 3.30.
July	15.............	3.29	65.80	Puerto Ricos.
"	18.............	3.20	64.00	Philippines.
Aug.	6..............	3.165	63.30	Philippines, 3.16, 3.17.
"	13.............	3.18	63.60	Cubas.
"	20.............	3.43	68.60	Philippines.
"	21.............	3.425	68.50	Puerto Ricos, 3.40, 3.45; Philippines, 3.45.
"	22.............	3.50	70.00	Cubas.
"	23.............	3.45	69.00	Puerto Ricos.
"	27.............	3.50	70.00	Puerto Ricos.
"	29.............	3.45	69.00	Cubas.
Sept.	6..............	3.50	70.00	

INDEX TO VOLUME XXXIX

(An asterisk preceeding a page number indicates that the subject is illustrated.)

Q

R

S

T

V

W

Y